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OBSERVATIONS ON ELECTRICAL PULP TESTING[1]

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In present day clinical practice, the chief purpose of pulp testing is to determine whether or not a pulp is normally vital. If not, it is desirable to ascertain to what degree degenerative processes have progressed. When degeneration has advanced to the point of necrosis, the resultant destructive action may often be easily determined in a radiographic study of apical and periapical tissue. The danger in the radiograph as an instrument of evidence, however, lies in its limitations; e.g., anatomical structures in bone and bone pathoses superimposed upon the shadow of the apex, which may or may not be associated with non-vital teeth, are open to misinterpretation. Moreover, the amount of other harmful change in the pulp, as well as necrosis not definitely ascertained clinically or radiographically, clearly demand a means of identification.

For this differential diagnosis, various methods have been devised. Many are based upon physiological principles of nerve stimulation through the use of electrical devices. Thus far, however, the available equipment of this nature, in our opinion has not been wholly satisfactory. It is our object in this discussion to analyze and evaluate methods and apparatus which we have used in an attempt to overcome some existing shortcomings, and to scrutinize these in the light of their efficiency as a source of more accurate information as to the condition of the pulp.

ELECTRO-PHYSIOLOGY

The normal pulp contains nerves, the receptors of which may be stimulated. The irritability of the nerve is dependent upon and

[1] Preliminary report read at a meeting of the New York Section of the International Association For Dental Research, June 4, 1936. Read at a meeting of the Staff of School of Dental and Oral Surgery, Columbia University, April 28, 1937. Preliminary report, February 13, 1935.

[2] Experiments performed while Dr. Wald was a student at the School of Dental and Oral Surgery, Columbia University.

varies with the metabolism of the pulp, which is in turn influenced by inflammatory, regressive, degenerative, or other physiological and pathological changes in the tissue. Often, in the process of attempting to stimulate the pulp, a simultaneous reaction is elicited in the peridental membrane. Such a response is without significance, since it is possible that the pulp pathosis will in no way affect the capacity of the investing tissues themselves to react to electric current. This accounts for the error commonly made of confusing a peridental membrane response with a pulp response, and the resultant vital diagnosis of a non-vital tooth. Accordingly, we are faced with the need for an improved mechanism which will separate the responses of the tooth and the investing tissues and accurately determine their thresholds.

For a comprehensive approach it is necessary to review the reaction of nerve to electrical stimuli. In order to obtain a response, a stimulus, which may be defined as a sudden change in environment, must have the following characteristics: 1) the change in environment must be sufficiently great; 2) it must occur within a limited time; and 3) it must be applied for a sufficient duration. Thus, if a direct current is applied to a nerve or to its receptor, it must be raised from zero to the necessary potential at an adequate rate of change, and must be applied for a certain minimal time. The absolute values of these characteristics will vary with the physiological condition of the tissues.

In considering pulp testing, the strength of the stimulus may be best expressed in current density at the receptor, or, for practical purposes, in total current, which is more easily determined. The current depends on 1) the applied voltage; 2) the resistance of the contact between the electrode and the tooth; and 3) the resistance of the tooth itself. Since the stimulating effect of an electric current is dependent upon the time-rate of change, the wave shape, which is an index of the time-rate of change, also assumes a functional rôle. As long as this factor is maintained constant and is reproducible, thresholds may be determined for any satisfactory wave shape, although determination of the optimum rate of change is of great interest. The duration of application may be a very small value, in which case effective stimulation would depend both upon time and

the magnitude, or, the stimulating effect might be designated as a duration at which a stimulus of minimum magnitude would be effective (if the current were reduced, it would cease to stimulate regardless of the time of application).

COMMERCIAL APPARATUS

Considering electrical pulp testers used by the dentist today in the light of the above factors, the following measurements were made on commercial instruments with the aid of a cathode ray oscillograph.

(A) A type in which galvanic current is used from either batteries or from a resistance in series with the D. C. line. Both electrodes may be applied to the tooth, or the cathode to the tooth and the anode to the hand. The method of making and breaking the circuit is usually by means of a button in the instrument in series with one electrode. Each time the button is pressed or released, the circuit is made and broken several times. The make and break may also be done directly on the tooth by applying and removing the electrode. The wave form here is irregular, depending upon the speed with which the button is pressed. This likewise affects the duration of the current, and no effort is made to control electrode-tooth resistance. Hence, innumerable variables enter which influence the diagnostic value of such devices.

(B) A type in which faradic current is employed. The current is drawn from the secondary of an induction coil, the input to the primary being interrupted A. C. or D. C. The details of construction as well as the method and frequency of interruption are as varied as the trade names. Here too, irregularities of wave form, distortion modulation, and inconstant and high frequency harmonics are found. A subdivision of this group is the type which employs a current having a range of frequencies the harmonics of which are well into the radio-frequency range. It is generated by an inductorium. Because of the high frequency only one electrode is needed; but this seeming advantage is offset by the tendency of high frequency current to travel along the surface rather than to penetrate as do lower frequencies, and consequently to increase the possibility of peridental membrane stimulation.

(C) A type which employs low frequency current derived from a transformer connected with the A. C. house line, and whose output is a pure sine wave. Although the wave form is constant, owing to other deficiencies to be discussed, this type tester when applied clinically disclosed inadequacies common to all.

THE PROBLEM OF PULP TESTING

I. *General statement.* Pulp-testing problems may be outlined thus: A. Intrinsic factors in teeth causing variations in resistance: 1) Thickness of enamel, 2) Thickness of dentin, 3) Pulp recession or other regressive changes and 4) Physiological characteristics of tooth. B. Peridental membrane reaction. C. Extrinsic factors: 1) Moisture, 2) Pressure of the electrodes, 3) Position of the electrodes on tooth, 4) Wave form of the testing current, 5) Inaccuracy of readings without an exact meter indication and 6) Description of response by patient and interpretation by operator.

II. *Laboratory studies.* In pulp testing the resistance factor is undeniably important since the fraction of the applied voltage which reaches the pain receptors is dependent upon the resistance in the circuit. We have determined by laboratory tests that the resistance between 2 electrodes 5 mm. apart when placed upon enamel of the canines of anesthetized dogs, from which the surface moisture has been removed, is over one million ohms. The resistance between 2 electrodes 3 mm. in diameter, 5 mm. apart in dentin is between 10,000 and 20,000 ohms. The possibility of such determinations coupled with those of impedance measurement serving as an objective criterion of tooth vitality led to a series of impedance measurements on the canines of anesthetized dogs. Two amalgam fillings were inserted in each tooth and impedance measurements made on vital and devitalized teeth. No definite conclusions were arrived at due to limitations of the apparatus used. However, some of the findings are worthy of note here: A. Following insertion of the fillings there seemed to be a definite tendency for the slope of the curve of the impedance of the dentin, as plotted against the frequency of the measuring current, to increase with time. We have interpreted this as evidence of secondary dentin deposition between the fillings. B. The phase angle of dog dentin is similar to that of human skin,

which differs from that of other tissues. C. The impedance of dog dentin varies as an inverse function of the applied frequency which corresponds with data on other tissues. Further measurements of impedance and phase angle with more refined apparatus and under varying conditions are worthy of future study.

III. *Human studies.* An outstanding clinical problem which may lead to erroneous interpretation of tooth vitality tests is the confusion of peridental membrane response with that of pulp response. In an attempt to distinguish these reactions more definitely the following technique was employed: the electrode was placed under the free gum margin or on the gum, and current applied. The investing tissues were thus stimulated and the patient informed that what he felt was "gum." A tooth of unquestioned vitality was then stimulated in the usual way and this sensation was explained to the patient as a "pulp response." An individual with normal sense perception can easily differentiate between the two reactions, thus providing a basis for more accurate diagnosis.

Continuing this technique, a series of experiments was conducted which demonstrated why so many teeth with unquestionably necrotic pulps give responses seemingly indicative of vitality. This misconstrued response may be attributed to the fact that the current is stimulating the membrane at a voltage below or so close to the point of pulp stimulation that conflicts are often encountered and non-vital teeth appear to respond. Although it is generally accepted that the peridental membrane response occurs because of conduction along the moist surface of the tooth, we could not verify this explanation in all cases—especially where care was used to dry and isolate the tooth thoroughly. Tests on questionable teeth revealed far more significant conditions under which peridental membrane reaction may be brought about. The following case is illustrative of the study material used, of the test employed, and of the reactions consistently noted.

The tooth in question showed definite radiographic evidence of periapical infection in spite of the fact that an electrical test was well within the so-called normal range for vitality. The diagnosis, based upon clinical symptoms, was a gangrenous pulp, which was confirmed by pulp extirpation. The canal was cleaned and dried with broaches and cotton points and the tooth again tested. This time there was no response. A moist cotton point was inserted into the root canal and there was again a response to the tester

at a low point on the scale, well within normal limits, although the tooth was isolated with a rubber dam and the surface of the tooth dry. This procedure was repeated several times on the same tooth. As a result of these experiments we are of the opinion that the electrical current is often conducted to the peridental membrane via the moist necrotic pulp rather than via the surface of the tooth.

IV. *Research apparatus.* The first apparatus set up embodied these features: a source of current providing a constant and known wave form; a means of accurate voltage and current readings; a stable, reliable electrode. In addition, with a view to establishing a current frequency more favorable to the separation of conflicting responses, a sinusoidal current was generated whose frequency could be varied from 35 to 50,000 cycles per second with meter voltage regulation.

It was observed that increasing the frequency from 35 cycles to 50,000 cycles brought the impedance down, while the threshold of irritability went up. In other words, although the tooth resistance was lowered, a greater amount of current was needed to reach the threshold of irritation. This fact seems to indicate that the proportional variations in nerve response to the varying frequencies are due to the physiological constants of the irritable tissues rather than the physical properties and constants of the intervening tissues. It was found further in some cases that when stimulating at low frequencies, (less than 500 cycles) the peridental membrane response was elicited at a threshold either actually or comparatively lower than the pulpal response; and that when frequencies of 1,000 to 5,000 cycles were employed, although a greater volume of current was required to establish the threshold of irritability, the relative position of pulp and peridental membrane responses was reversed, the pulp response now being elicited at a lower threshold. The wave forms of the currents here discussed are constant, and are comparable to a sinusoidal wave differing only in their peaked character. They are not to be confused with high frequency faradic currents.

The effect of varying the frequency may be illustrated in the following manner: 1) By placing the electrode on a tooth, then directly on the gingiva. 2) By placing electrode on a metal filling with margins extending beneath the gingival border. In several of our tests, the pulp was stimulated before a gingival response was felt when the higher frequencies were used. In some, the converse was true when the lower frequencies were employed.

This observation is compatible with the work of other investigators (1) who separated the reactions of two contiguous tissues by making use of their differing constants. This was accomplished by determining the stimulating frequency which would separate their responses most widely.

In order to test the practical value of the data described, a second device, consisting of a thermionic tube oscillator with a modified Hartley circuit, was constructed. This equipment differed from the first apparatus chiefly in that it was designed to deliver approximately 1000 cycles. The electrode used consists of a hollow silver tube bent to the shape of a contra-angle into which is inserted tightly a wooden plug projecting beyond the metal. The output was measured during all tests. Two machines of this type—one giving readings in volts and the other in microamperes—were installed in the Diagnosis Clinic, and through their daily use further information of a practical nature has been recorded.

V. *Voltage measuring tester.* With this appliance we received a fairly accurate indication of pulp vitality, and some degree of quantitative changes in the pulp were revealed when studied in comparison with control teeth. However, certain variations in the quantitative determination were noted under the following circumstances: when the electrodes were applied to different surfaces of the same tooth or different points of the same surface; when electrodes of differing sizes were used; or when the electrode was placed on a metal filling or bare dentin. In some cases it was observed that a high voltage was required on placement of the electrode on a given area, over sound enamel; but by moving the electrode a fraction of a mm. a pulp response was elicited at much lower voltage. Likewise, an electrode 1 mm. in diameter required a voltage materially higher than a 3 mm. electrode in the same area. Some of these variations may obviously be explained on the ground of tooth resistance, which brings us to the assumption that the necessary voltage is proportional to the resistance. However, the phenomenon of a great threshold variation when the electrode is moved a fraction of a mm. may be accounted for through physiological differences in the same tooth. Such an hypothesis is given credence by the recent findings of Bodecker and Lefkowitz (2) in their study on the diffusibility of dyes in vital teeth.

It is not our intent to charge that voltage determinations are value-

less. On the contrary, we believe that when the differences noted fall within a limited range of variation, and conditions under which tests are made are kept as nearly alike as possible, quantitative deductions have some merit.

VI. *Current measuring tester calibrated in microamperes.* A comparative evaluation of the recordings in microamperes is significant. When an electrode was shifted from place to place on a tooth, the required current was usually not appreciably altered. Neither was it altered when the electrode was placed on an occlusal metal filling or the enamel of the same tooth. Electrodes of unlike diameters stimulated with a like amount of current. As a consequence of these observations, we feel justified in the opinion that current readings constitute a more reliable index of nerve irritability than the popular method of recording by voltage. Moreover, our former conclusion that voltage must vary with the resistance or physical characteristics of the intervening tooth structure is further substantiated. Since the current required varies with the irritability of the nerve, rather than with the resistance of the tooth, the current recording machine overcomes and reduces to insignificance one of the greatest hindrances to accurate pulp testing; namely, tooth resistance.

A theoretical explanation of the advantages observed in the measurement of stimulating current over voltage is elicited in the following: enamel, dentin, mucous membrane and skin, show wide variation in impedance in different individuals; and in the same individual at different times. However, the impedance of internal membranes, except in cases of pathosis, are relatively constant. Consider then, the case of the enamel, dentin and the membrane around the irritable pulp tissue all connected in series. This serves as a simplification of an actual case of a current stimulating the pulp of the tooth. The electrical circuit would be as in *fig. 1.*

The potential across any resistance is equal to the current passing through it, times the resistance. Therefore, the difference of potential between both sides of the membrane around irritable pulp tissue is the product of the current times its resistance. When a current is passed through the enamel and dentin, their potential drop will vary with their resistances. However, since the impedance of the internal membranes in normal cases is relatively constant, the poten-

tial of the irritable tissue in respect to its environment remains the same for the same current, regardless of the enamel and dentin resistance or the voltage applied across the entire circuit.

VIII. *Statistics.* A recent series of 200 pulp tests[3] on questionable and control teeth, conducted with the current-reading apparatus,

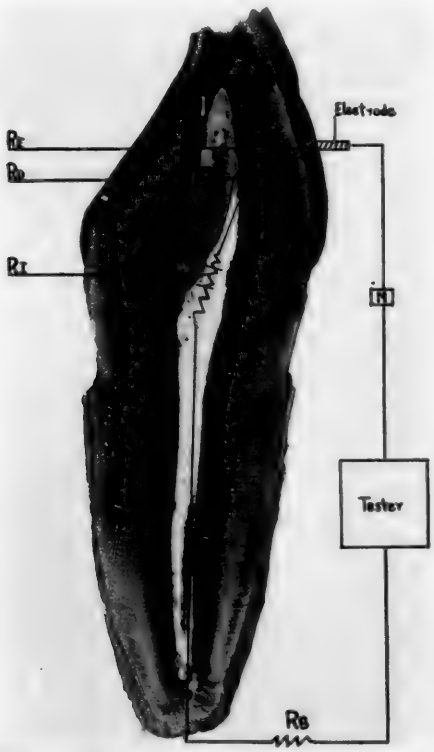

Fig. 1. Re—Enamel Resistance; Rd—Dentin Resistance; Ri—Internal Membrane and Resistance; Rb—Body Resistance; M—Meter.

showed 49 teeth to be non-vital. These findings were confirmed by repeat readings, x-rays, and pulp extirpation. Of the remaining 151 vital teeth, close repeat readings were obtained in 135. Sixteen tests

[3] These tests conducted by various members of the Oral Diagnosis Staff.

disclosed variations great enough to be regarded as discrepancies. In the entire series, identical repeat readings were obtained in 102 cases.

IX. *Technique.* Throughout the study the following technique was used. The tooth was isolated with cotton rolls and thoroughly dried with compressed air. The electrode was soaked in a saturated salt solution and held in firm constant contact while tests were made. This provides an even surface of moisture and permits the use of a comparatively larger surface contact. The electrode was placed first upon the gingiva to give the patient the experience of a peridental membrane response, and then upon a control tooth for the sensation of a pulp response. In conjunction, an indifferent hand electrode was used. Voltage is slowly increased to the point where the patient reacts. (Patient is instructed to raise his left hand when the current is first felt.) Current readings are taken directly from the meter. Repeat readings follow. Strict adherence to the technique is imperative. Faulty details such as a film of moisture, moist cotton rolls in contact with the tooth and gingiva, or poor electrode contact are quickly detected by erratic current readings. These fluctuations are caused by resistance changes due to surface leakage of current. While similar care must be exercised with prevalent commerical equipment, errors in technique are not readily discernible and are often misinterpreted.

DISCUSSION

The use of a current-recording device such as has been described, employing a frequency seemingly more suitable to pulp than to peridental membrane stimulation, encourages optimism as to possible future developments in electrical pulp testing. Whether or not our present apparatus can adequately answer all questions relating to the status of a pulp, we are not prepared to state at this time. The machine, in use clinically, is being refined and improved. The accuracy of its recordings are verified with histopathological studies.

In a previous report (3), it was stated that work was being done on chronaxie measurements in pulp testing. The machine was constructed, but repeated tests seemed to indicate that these determinations, although theoretically sound in other fields, were here unreliable because of inability to obtain repeat readings.

SUMMARY

1. Physiological aspects of pulp vitality were studied by electrical means which disclosed: (a) that tooth impedance varied inversely with stimulating frequency, (b) that threshold of stimulation varies directly with frequency of stimulating current, (c) that frequencies between 1,000 and 5,000 cycles seemingly separate the pulpal and peridental membrane responses in some instances. 2. Thermionic tube oscillators were constructed for clinic use, the outputs of which are measured with a voltmeter and microameter. 3. Voltage and current readings were evaluated and compared. 4. A series of tests were conducted on questionable and control teeth with apparently significant statistical results.

CONCLUSIONS

1. There appear to be favorable frequency ranges for determining thresholds of stimulation in pulp testing. 2. The technique for pulp testing is critical in all of its details and must be strictly adhered to. 3. Current-reading apparatus, in our hands, has proved superior in determining thresholds of pulp irritability to other devices which we have employed.

We wish to acknowledge our indebtedness to Doctors Kenneth S. Cole, Barry G. King and H. B. Williams, of the Department of Physiology, College of Physicians and Surgeons, Columbia University, and Leo Mackta, School of Dental and Oral Surgery, Columbia University, for their valuable suggestions and the use of equipment during the course of these experiments.

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ERRORS DEVELOPED BY THE USE OF CENTRAL BEARING POINT IN ADJUSTMENT OF ARTICULATORS

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All 3 dimensional articulators require the use of centric, lateral and protrusive checkbites for their adjustment. We have observed errors in the occlusion of dentures built on this type of instrument when a central bearing point was used in obtaining these checkbites. Part of this error was believed to be due to a mechanical reduction of the space between the maxilla and mandible, when eccentric records were taken. This change of relationship was tested by comparative measurements taken at definite points on 2 flat plates, mounted on an articulator.

These plates were provided with a means of making their relationships either central bearing or lateral bearing; without changing their vertical separation, while in centric relation. Three millimeters of protrustion was made for all recordings other than centric. The condylar inclinations were set at 30 for the recordings which will be shown. Measurements of the space between the plates were taken at the molar and the cuspid regions on each side, with a vernier caliper. Measurements were recorded first with the articulator in centric relation for a control. The amount of separation between the plates was the same in centric with both central and lateral bearing points.

The articulator was locked in lateral protrusion. Measurements were recorded with a central bearing point and with a lateral bearing point on the "working" side. By comparing these recordings it will be seen that the distance between the 2 plates was less when the central bearing point was used, than when the lateral bearing point was used. This amounted to .2 mm. in the molar region, and .6 mm. in the cuspid region. With a central bearing point, the space between

the plates on the "working" side, in lateral protrusion, is less than on the same side in centric relation (Table I).

TABLE I

RIGHT LATERAL PROTRUSION	RIGHT MOLAR	RIGHT CUSPID	LEFT CUSPID	LEFT MOLAR
Centric	3.8	5.0	4.9	4.2
With lateral bearing point	5.0	5.8	4.6	4.2
With central bearing point	4.8	5.2	4.0	4.0
Amount of closure with central bearing point	.2	.6	.6	.2

Condylar inclination 30°
Amount of protrusion 3 mm.
Measurements in mm.

FORWARD PROTRUSION	RIGHT MOLAR	RIGHT CUSPID	LEFT CUSPID	LEFT MOLAR
Centric	3.8	5.0	4.9	4.2
With incisal bearing point	5.4	5.0	4.9	5.8
With central bearing point	5.0	4.0	3.9	5.4
Amount of closure with central bearing point	.4	1.0	1.0	.4

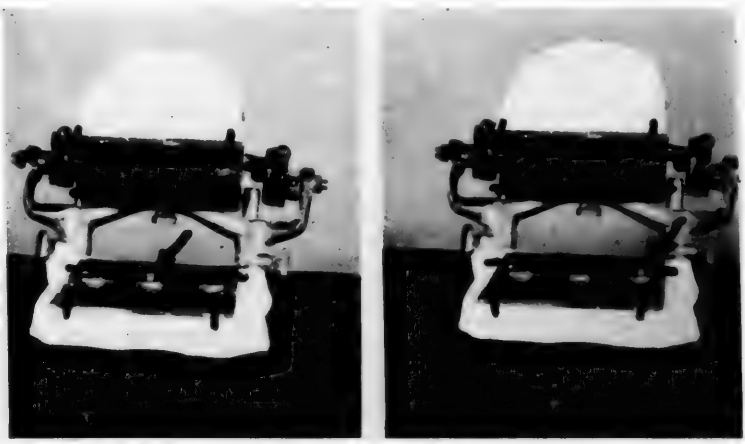

Fig. 1. Flat plates mounted on articulator. Arrows indicate interchangeable bearing points. Marks on plaster show points at which measurements were taken.

The articulator was next locked in forward protrusion. Measurements were recorded with a central bearing point, and with an incisal bearing point. It can be seen that there is a closure of 1.0 mm. in

the cuspid area, and of .4 mm. in the molar area, when the central bearing point is used for forward protrusion records, as compared to those taken with an incisal bearing point. The distance between the plates in the incisal region is less in protrusion than in centric when the central bearing point is used. Steep condylar inclinations produce greater amounts of closure than those which are more nearly horizontal.

The technic for the use of most 3 dimensional articulators includes the arbitrary raising of the height of the central bearing post for forward and lateral checkbites. This is to allow for cusp height and incisal overlap. It can not be considered to correct the closure just described. Vertical dimensions and incisor relationships must be determined in the mouth before lateral and protrusive checkbites may be taken. Therefore, any closure recorded in these lateral and protrusive checkbites will decrease the cusp height and shorten the incisors by that much.

Due to the fact that the condylar inclination is one of the variables in denture construction, proper allowance for additional vertical opening in lateral and protrusive records cannot be made.

There are 2 possible methods of avoiding these errors. First by the use of a lateral bearing point for lateral checkbites and by the use of incisal bearing points for protrusive checkbites; and second by predetermining the condylar inclination and then making the proper adjustment of the height of the central bearing point.

DECALCIFICATION VERSUS MECHANICAL INJURY IN CARIES[1]

EDMUND APPLEBAUM, D.D.S. AND T. HOLLAND ADAM, A.B.

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The results of the experiments of several workers have indicated a relationship between dental caries production and physical character of the diet. Rosebury, Karshan, and Foley (1) have shown 3 distinct types of experimental dental lesions in rats, all produced with diets containing coarsely ground cereal particles: **1**) Beginning in enamel at base of molar fissures, **2**) Resulting from fracture of cusp, **3**) Beginning in dentin at the cusp summit. Only the first seems comparable to human caries. Four degrees of progress of the fissure-caries lesion have been described, which were later (2) extended to comprise ten stages: **1**) Penetration of the enamel diffusely or through enamel lamellae (stage 1), **2**) Spread at dentino-enamel junction (stages 2 to 4), **3**) Penetration of dentin by infiltration of the tubules and disintegration of the dentin matrix (stages 5 to 7) and **4**) Loss of surface continuity and formation of a cavity (stages 8 to 10). These workers have reported that the occurrence of fissure caries seems to be independent of the calcified state of the tooth (1, 2, 3). They stated that:

> "In rats the action of large particles in producing fissure caries may be explained—if we assume that dental caries arises by bacterial action on food particles retained at sites about the teeth,—by postulating a process of forcible impaction-wedging—of such food particles into favorable regions. Such forcible impaction may act (a) by perforating the enamel cuticle and bringing the food mass into intimate contact with enamel, and thereafter (b) by resisting normal mechanisms that remove or replace food masses less effectively impacted."

King (4) suggested that a mechanical injury of enamel in rats and perhaps in man has some significance in the etiology of caries. He believes rat fissure lesions are preceded in some instances by a "crack"

[1] Presented at the 16th General Meeting of the International Association for Dental Research, Minneapolis, March 12–13, 1938.

at the base of the fissure, although in other instances "a more or less diffuse area of enamel decalcification occurs."

These alternative mechanisms of caries penetration clearly correspond with the "lamellar" and "diffuse" enamel lesions of the previous workers (Rosebury et al.). Whether the so-called "lamellae" are actually cracks in some or all of these instances has not been demonstrated. Bodecker (5–6) who first described enamel lamellae as organic structures in 1906, noted the similarity of enamel lamellae to cracks in 1928.

FIG. 1

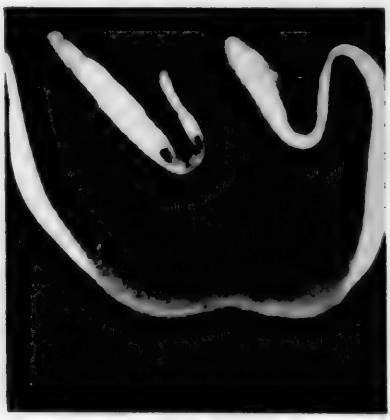

FIG. 2

FIG. 1. Photomicrograph of ground section of molars of experimental rat with "crack" (C) at base of fissure and diffuse lesion in enamel.

FIG. 2. Soft x-ray picture of ground section seen in *fig. 1*. Crack at base of fissure is radiolucent and so is adjacent diffuse lesion.

Mandibles and ground sections of mandibles of rats were obtained from Dr. Rosebury. These were from experimental animals which had been fed on a coarse particle diet and showed, microscopically, fissure caries exhibiting "cracks" or "lamellae" at the bases of the fissures. Similar "cracks" or "lamellae" at the bases of fissures are also seen microscopically in ground sections from control animals without caries. Studies of these ground sections by soft x-rays (7) revealed radiolucent lines in the enamel at the base of the fissures in both control and experimental animals. The soft x-ray cannot

differentiate between a crack and an organic lamella, both being radiolucent. In *figs. 1 & 2*, however, a diffuse decalcification is seen at the side of the "crack" in the fissure caries of the experimental animal which is not seen in the control animal. *Fig. 1* is a photomicrograph of a ground section of the molars of an experimental animal with a "crack" at the *base* of a fissure in the first molar and an adjoining diffuse lesion in the enamel. *Fig. 2* is a Grenz ray picture of this section showing the radiolucent crack and the decalcification of the adjacent enamel. *Fig. 3* is a photomicrograph of another

FIG. 3

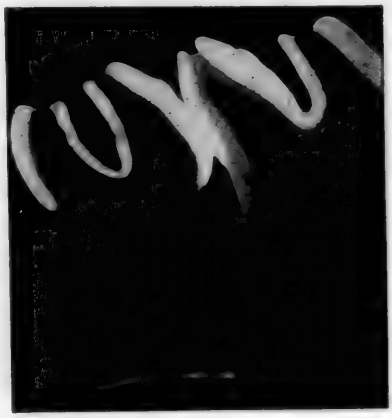

FIG. 4

FIG. 3. Photomicrograph of ground section of molars of experimental rat with a "crack" (C) at side of fissure of third molar. "Cracks" may also be seen at base of fissure in second molar.

FIG. 4. Soft x-ray picture of ground section seen in *fig. 3*. Under conditions employed, shows radiolucent crack at side of third molar fissure and decalcification of enamel as well as dentin.

experimental animal with a "crack" at the *side* of the fissure of a third molar with evidence of a change in enamel and dentin. *Fig. 4* is a Grenz ray picture of this section showing the radiolucent crack at the *side* of the fissure with the adjoining decalcification of enamel and dentin.

It is worthy of note that in sections from the control animals (free from caries) "cracks" were also seen. However, Grenz rays of such

sections showed no corresponding radiolucent bands; the "cracks" in these sections did not exhibit sufficient radiolucency in contrast with the surrounding enamel to make them stand out. It may be noted that the "cracks" seen at the bases of the fissures in the second molar in the ground section shown in *fig. 3* do not show in the corresponding Grenz ray picture (*fig. 4*). This was due to the fact that this Grenz ray picture was exposed to bring out the "crack" in the third molar. The other crack might have been demonstrated by changing the exposure. In explanation of the clarity with which

FIG. 5

FIG. 6

FIG. 5. Photomicrograph of ground section of human molar. Incipient enamel caries (C) is seen on approximal surface with tract of affected dentinal tubules (A).

FIG. 6. Soft x-ray picture of ground section seen in *fig. 5* shows decalcification of enamel on approximal surface together with calcific changes in dentin.

the "crack" is distinguished from the surrounding structures in the third molar area of *fig. 4*, and in other experimental animals, it may be that acid has penetrated into the "crack" and widened it; whereas in the control specimens, although "cracks" are present, acid has not been produced, widening has not occurred, and the Grenz ray has failed to demonstrate their presence.

Fig. 5 is a photomicrograph of a human molar with proximal incipient caries of enamel and dentin. *Fig. 6* is a Grenz ray picture of this section showing enamel decalcification and dentinal changes. *Fig. 7* is a photomicrograph of a human molar with incipient caries

of the enamel in an occlusal fissure. *Fig. 8* shows beginning decalcification at the base and sides of this fissure.

FIG. 7

FIG. 8

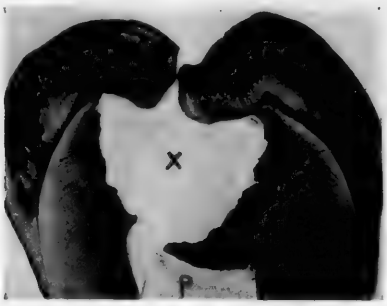

FIG. 9

FIG. 7. Photomicrograph of a ground section of human molar. Incipient caries of enamel in occlusal fissure.

FIG. 8. Soft x-ray picture of ground section seen in *fig. 7*. Discloses beginning decalcification at base and sides of fissure.

FIG. 9. Photomicrograph of ground section of human molar with extensive destruction of dentin at X. Although enamel has been undermined it has not yet fractured. P—Pulp chamber.

It cannot be said that this study settles the question whether the structures seen in rat jaw sections are actually cracks induced mechanically or lamella present as developmental structures. The pres-

ence of such structures in rat jaws without caries seems to invalidate the idea that they initiate the process. In rat teeth with incipient caries the Grenz ray evidence indicates that decalcification of the enamel is present in addition to the crack or lamella; and the decalcification would seem to be the cause of enamel destruction, in accordance with the theory of W. D. Miller (8). All this applies to human teeth. In support of this concept, a photomicrograph of a human molar is shown, with extensive cavity formation in the dentin (*fig. 9*). In this tooth, although the enamel is undermined, it has not fractured. The point to be stressed is that, with decalcification (9) alone, extensive destruction of tooth structure can take place, without aid of any mechanical factor. Here certainly the mechanical factor may play a secondary rôle in removing decalcified tissue debris.

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STUDY OF ASCORBIC ACID BLOOD LEVELS IN DENTAL PATIENTS

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Histories of low Vitamin C intake have been frequently obtained from patients attending the various departments of the dental school clinic. The effects of Vitamin C deficiency on dental structures have been studied experimentally by Wolbach and Howe, 1926 (1). Hanke, 1933 (2), observed clinical improvement in the gingiva following the use of large amounts of orange juice and suggested that the improvement in the gingival condition was due to Vitamin C in the orange juice. No method at that time was available for determining Vitamin C deficiency, and synthetic Vitamin C had not then been isolated. Recently Boyle (3) described, in Vitamin C deficient guinea pigs, parodontal changes which are pathologically identical with a form of human parodontal disease.

Clinical studies on Vitamin C nutritional states have been aided by the isolation of synthetic Vitamin C and by the introduction of laboratory methods for determining the concentration of Vitamin C in the blood. Using one of these methods, a study has been made on the state of Vitamin C nutrition in 65 dental patients. Fifty of the 65 were among others sent to this department for a general medical examination. They were not selected because of the presence or absence of parodontal disease. Feeding experiments were carried on with the remaining 15. These were chosen because of the coexisting parodontal disease and Vitamin C deficiency.

METHODS

All patients were given a complete medical examination as well as a special examination of the oral structures. Diet histories were obtained with special reference to the intake of Vitamin C for a period of at least one month. Reasons for low intake were noted. The patients appeared for examination after being on a Vitamin C free diet for 12 hours.

Blood Study: The method used was found to be the most satisfactory and is based on

the work of several authors (4, 5, 6, 7). 10 cc. of venous blood is removed in an absolutely dry syringe. The blood is allowed to run out of the syringe into a dry centrifuge tube containing a small amount of powdered potassium oxalate. 1 drop of a 2 per cent solution of potassium cyanide is added to the blood and the tube inverted several times, care being used to prevent hemolysis. The blood is then centrifuged for 5 minutes at 900 R.P.M. 2 cc. of the clear plasma is withdrawn into a small beaker, 4 cc. of distilled water is added, and the solution is deproteinized by the addition of 4 cc. of a 5 per cent solution of metaphosphoric acid. The mixture is stirred throughly and quickly filtered through a fluted filter paper. A 5 cc. portion of the filtrate is removed and titrated directly with .01 per cent indophenol. A 5 cc. burette graduated as fine as .01 cc. is used. The dye is standardized by a freshly weighed ascorbic-acid solution. All solutions are kept in the ice box and made fresh every week. The calculation is based on the burette reading minus the blank times the dye factor (8).

Feeding: Following an initial determination, Vitamin C was administered to 15 patients. No change was made in their present diet, and the vitamin was in the form of tablets each containing 25 mg. of Vitamin C. 1 gram of the vitamin was given over a period of 5 days in divided doses of 200 mg. per day. A second determination of the blood concentration was then made, and at this time, as well as at all subsequent determinations, symptoms and findings were recorded. The feeding of the vitamin in doses and periods as stated above was continued until a blood level of at least 1 mg. per cent was reached. At this time a few patients were placed on a maintenance intake of 50 mg. of Vitamin C per day, and the blood concentration was determined at the end of three weeks. At this time the patients were placed on their regular diet free of synthetic Vitamin C but containing at least 2 oz. of orange juice for three weeks when a final determination was made.

RESULTS

History: Low intake of Vitamin C was associated with the following histories: 1) Gastro-duodenal complaints, 2) Prescribed deficient diets in colitis, 3) Economic conditions, 4) Allergic states, 5) Dislike for ordinary food sources and 6) One patient with permanent colostomy.

Titrations: In 65 patients titrated for Vitamin C content of blood the following range levels were present:

36 pt.	.00 mg. per cent–.57 mg. per cent
11 pt.	.60 mg. per cent–.85 mg. per cent
18 pt.	1.00 mg. per cent or greater

All low blood levels, i.e., .000 mg. per cent to .8 mg. per cent were associated with a history of low intake while the levels above .8 mg. per cent occurred in patients with adequate Vitamin C intake.

Dental findings: There was no specific lesion associated with low blood concentrations. In all such cases, however, there was always present some degree of congestion of the gingiva. This congestion

in some instances was limited to about a 3 mm. portion of the marginal gingiva. In others it involved the entire labial or buccal alveolar mucosa. The more marked the deficiency, the greater the sponginess of the tissues. Tissue hypertrophy was present in many of the younger patients. In older patients, various degrees of congestion of the gingiva were frequently associated with pocket formation and mobility of teeth. The most frequent symptoms were bleeding and soreness, while a few patients complained of loosening of the teeth. In the 18 patients whose blood concentration was 1 mg. per cent or greater, obvious loss of bony support was present in two cases. The more profound changes associated with low blood concentration,—that is, involvement of gingiva, gingival attachments, pocket formation, suppuration, and mobility of teeth,—were present only in patients above the age of 20. In the present paper no attempt is being made to classify changes in bone.

FEEDING STUDIES

Fifteen patients have been studied on the basis of response to the administration of Vitamin C. These have been divided into groups: Group A with initial blood concentration below .45 mg. per cent and Group B greater than .45 mg. per cent.

GROUP	INITIAL TITRATION	TITRATION AFTER INGESTION OF 1 GRAM VIT. C	CLINICAL IMPROVEMENT	TITRATION AFTER INGESTION OF 2 GRAMS VIT. C	CLINICAL IMPROVEMENT
	mg. per cent	*mg. per cent*		*mg. per cent*	
A	.00–.45	.35– .68	none	1.0–1.40	+
B	.45–.72	.90–1.43	none	1.2–1.65	+

Following the ingestion of the first gram of Vitamin C given over a period of 5 days, there is subsequent rise of from .3–.7 mg. per cent in the blood level. Group A cases with initial blood values below .45 mg. per cent require more than 1 gram of Vitamin C before normal blood levels are reached, while Group B cases attain normal blood values after the ingestion of the first gram of the vitamin. An interesting observation is the apparent time necessary for clinical improvement to occur after normal blood values are attained. No clinical change was observed until approximately 2 weeks after the ingestion of the vitamin even though normal blood values were

reached in some cases after the ingestion of 1 gram of Vitamin C given over a period of 5 days.

Patients placed on maintenance doses of 50 mg. of the synthetic Vitamin C per day maintained normal blood levels and clinical improvement over a two weeks period. Following the withdrawal of synthetic Vitamin C, all but 3 patients could be satisfactorily maintained by adding 2 oz. of orange juice to their diet. The 3 exceptions were patients with colitis in whom normal blood values and clinical improvement were difficult to maintain when synthetic Vitamin C was withdrawn.

The observed clinical improvement consisted in cessation of bleeding, diminished hyperemia, increasing firmness of tissue, and in a few cases tightening of the teeth.

The subjective improvements reported by the patients included an increased sense of well being and better appetite.

DISCUSSION

Until very recently partial Vitamin C deficiency was a suggested clinical possiblity, but it lacked corroborative laboratory evidence. Since the introduction of chemical methods for assaying ascorbic acid in blood, various blood values have been determined in a large number of patients. It is generally agreed that the normal ascorbic-acid content of blood falls somewhere between 0.7 and 2.0 mg. per cent. Ingalls (9) recently described three groups in infants:

1. Optimal intake	0.7–2.0 mg. per cent
2. Suboptimum	0.30–0.50 mg. per cent
3. Deficiency	Less than 0.30 mg. per cent

The words "subclinical scurvy" have been frequently used as a loose general term to denote a nutritional state located somewhere between acute scurvy and the normal. At present, we mean blood ascorbic values between 0.25 mg. per cent and 0.7 mg. per cent. In our patients, various degrees of parodontal disease were present when blood ascorbic values were less than 0.7 mg. per cent. But the picture of parodontal disease in the human being is complicated by factors other than a partial deficiency of Vitamin C, such as mechanical stress or the presence of bacterial infection. The failure of Vitamin C

therapy to produce complete cure in certain long-standing cases of parodontal disease associated with partial deficiency obliges us to consider the whole pathological sequence of the disease process. Deficiency of Vitamin C causes primarily chemical alterations in the tissues (Wolbach and Howe (1)). Later structural lesions occur, and after these have persisted without treatment for a period of time, they will not revert to normal when Vitamin C therapy alone is instituted. Thus it is impossible in the long-standing cases to separate Vitamin C and the other factors involved in parodontal disease and to specify the rôle played by any single factor.

All of the cases of partial Vitamin C deficiency in this study can at present be classified into one large group, that of sub-optimal intake, though we do not deny the possibility of abnormal assimilation or utilization in cases of normal intake.

CONCLUSION

Partial Vitamin C deficiency causes some degree of parodontal disease.

Replenishment with Vitamin C is followed by normal ascorbic blood values and clinical improvement in the tissues affected.

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ENDOCRINE THERAPY OF PARODONTOSIS

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The problem as to whether parodontosis is to be regarded as a local manifestation of a general disease, or not, is of definite therapeutic interest. However, it is to be stated that, to the author's knowledge, no parodontosis has ever been cured by a strictly internal treatment, and that there is hardly any hope of ever achieving this.

The treatment of an internal chronic affliction, or systemic anomaly, present in parodontosis, merely aims at creating better conditions for the local treatment that is to be given by the dentist, and at excluding the high probability of relapses. Many authors have had the experience that the local treatment would be effective only if the chronic condition was treated simultaneously. Landgraf has found that in cases where the chronic condition was not treated, the local treatment effected poor results. Charbonnier calls it "nonsense" to treat a case of parodontosis without first examining the status of the general conditions. Willman, though, is of a different opinion: he states that the local treatment suffices, and the removal of calculus had always been sufficient. My own views on the organotherapeutic therapy of parodontosis are based on approximately 500 cases which I have treated myself. The local treatment in these cases has invariably been performed by dentists.

A glandular affliction which might be simultaneously present in parodontosis may well be cured spontaneously in that other glands step forward to do the work of the afflicted ones. A superficial analysis may find a functional disturbance in the second gland only, as is frequently the case, especially if this particular disorder appears to predominate in the clinical picture; this usually leads to a treatment of this disorder, and the primary is overlooked. Such action would be of definite harm to the patient, in that it would be apt to disturb any systemic endeavour in compensating the functional disorder in

gland I by changing the function of gland II. This has been demonstrated on a large scale by Abelin in animal tests. Clinical observations have been repeatedly published, i.e., the increased metabolism in adiposity has thus been explained. Here is the history of one case, a girl, 16 years of age, who suffered from parodontosis:

> The girl measured 159 cm, weighed only 44.3 kg; was underweight approximately 15 kg. The internal organs were found to be in good order, no signs of a thyroid affliction, blood pressure: 100:65. The basal metabolism was −15%, the specific dynamic action was normal. The lowered basal metabolic rate may, in this case, be explained by an endeavour on the part of the organism to prevent a further assimilation of fat, a symptom which is almost regularly met with in chronic malnutrition. This statement is based on my own findings. It would be definitely erroneous to administer thyroid in such a case because it would only tend to hamper the curative process.

Organic afflictions of the internal glands play no great part in the pathogenesis of parodontosis. If there happens to be one, all we have to do is to follow the general therapeutic principles. In the large majority of cases the disorder is of a functional nature.

In cases where there is a hyperfunction of a gland, the latter may be partly destroyed by either operation or radiation. Frequently, sedatives, or the counter action of other glands, will suffice. For example, the thyroid and the thymus are to be regarded as antagonists. I have observed this fact in numerous cases of my own.

If there is an insufficiency, we have to resort to some one of these measures: substitution therapy, increase of a correlative glandular function, hyperemia, etc. In substitution therapy, the hormone, even if administered in the ideal form, can never equal the natural hormone in therapeutic effects. Instead of normal, continuous formation and secretion, the body is suddenly swamped. The fine regulations, apt to govern the effect produced by the natural hormone, are necessarily lacking as well. Thyroid preparations may be employed to advantage in cases where parodontosis appears to be associated with a hypofunction of the thyroid.

Weinmann's hypophyseal parodontosis presents a sharply circumscribed type. Pituitary preparations frequently furnish excellent results in this condition. I present one of my own cases to illustrate this statement:

Female patient, 32 years of age. Absence of libido and orgasm. Menstrual deficiency, menstruation lasting less than 1 day. The patient measured 159 cm, and weighed 96.5 kg. Blood sugar curve: On empty stomach, 90; after 1 hour, 105; after 2 hours, 93. Basal metabolism normal. Specific dynamic action after 1 and 2 hours, respectively 5.3% and 6.2%; also markedly decreased. Patient had been treated for a long period of time for parodontosis. There have been numerous relapses, though. As soon as the patient had, for some time, undergone the following treatment—pituitary medication, diathermy, change of diet—I received a note from her dentist informing me that he had never before seen the patient's parodontotic condition improved in such a striking form.

Equally satisfactory results have been reported by Sucher in three cases of inflammation of the parodontium where parathyroid medication was given.

Several cases of parodontosis in which diabetes mellitus appeared to be present, cleared up as soon as insulin was used.

The question as to whether parodontosis associated with Addison's disease may be successfully combated by the use of cortin, has to remain unanswered for the time being.

Many authors attribute importance to the use of ovarian preparations in the treatment of parodontosis. Thibault has used them to great advantage in 71 cases. G. Morelli writes that in cases where ovarian disorders have been found, a possible parodontosis "improved in a surprising way with following hormone therapy." Coën justly states that "le traitement opothérapeutique . . . n'est pas dirigé contre la pyorrhée elle-même, mais contre les troubles du tempérament qui l'a conditionnent."

Some authors, with Biedl among them, ask for the use of massive doses. The necessity of being rather careful in avoiding overdosing, however, may be seen with the insulin shock, with thyrotoxicosis, with hypercalcemia (overdoses of parathormone). On the other hand, small doses, even homeopathic ones, have been proposed. I have observed that in some cases which did not seem to react to any other measures, tiniest doses of thyroid organic substance cause definitely favorable results in Graves' disease.

Painting the A. ovarica, or A. spermatica, with phenol solutions (Doppler) is a surgical measure entirely too drastic to be employed in such cases. However, both Biedl and Doppler report that it resulted in the vanishing of a parodontosis which may have been present.

Physical measures, such as the ice-bag tie, the various forms of light and radiation treatments, etc. are also of therapeutic importance. Galvanization of the thyroid has been found of value in hyperfunction of the thyroid. Bucky's border rays (*Grenzstrahlen*) have, as yet, not been given their deserved place in the therapeutic armamentarium. They do not constitute a specific therapy, but a general stimulation therapy. Their therapeutic value may be illustrated by the mentioning of this case:

A male patient has for several years been treated for a "relatively slowly progressing" Addison's disease (cortin and salt therapy were, at that time, unknown factors). Then the patient was subjected to Bucky's ray treatment. The result was striking. Not only was the progressive course arrested, but the condition was decidedly improved. This patient had, simultaneously, suffered from a parodontosis. There were numerous relapses. As soon as the ray treatment was instituted, the parodontosis vanished, and did not recur during a two years' observation period.

Hypophyseal parodontosis yields readily to diathermy of the pituitary gland.

The regulation of the diet is of tremendous importance. Hawkins goes so far as to state that human beings who are free from infections, "by strict cooperation as to diet, place themselves in such metabolic balance that dental decay and systemic pyorrhea are impossible"—a statement which, in my own belief, goes a little too far. In parodontosis, Charbonnier demands the complete cessation of alcohol consumption; Bircher-Benner recommends the plentiful use of fresh fruit and vegetables. He believes that in some cases this thorough dietetic change will suffice to clear up the stomatological condition. According to Sturm, parodontosis is an affliction caused by endotoxins. Excretions located in the intestines form the receptacle for the autotoxins. It has to be the aim of any therapy to remove such autotoxins in parodontosis which, in 60 per cent of all cases, may be traced back to faulty diet. He forbids the intake of eggs, cheese, brain, liver, and recommends the use of 4 to 5 apples a day. Herrenknecht and Scheidt strongly advocate the administration of vitamin B in parodontosis—in opposition to Entin who regards parodontosis to be the result of an absence of vitamin C. Vitamin A is present in so many plants that one can hardly speak of a lack of this vitamin. Mellanby, however, holds a different attitude: she claims that one-fourth of

all cases of gingivitis and parodontosis are due to an absence of vitamin A in the diet.

Too little use is made, as yet, of the balneological therapeutic means. However, they are excellent in effecting a systemic change, either by increasing cellular oxidation, or by causing a better blood flow (Wiechowski). Alkaline waters are recommended by Charbonnier.

The heavy metals enjoy an excellent reputation in the treatment of parodontosis. Different metals are used—for example, arsenic, advocated as stovarsal by Béal and given as potassium arsenite by G. H. Belding and L. F. Belding. If there is a secondary anemia, so frequently present in parodontosis, iron should be given. Iodine may be justified in hyperthyrosis if given in small doses. However, no iodine-containing dentrifrices should be used; they frequently cause the manifestation of iodine poisonings. I have been using copper for several years. According to Underhill, Orten and Lewis, iron is immediately absorbed when given in combination with copper —this being an effect which is not produced by any other metal. The anti-anemic importance of copper is emphasized by Hart, Steenbock, Waddell and Elvehjem. The combination of iron and copper permits of achieving the highest therapeutic potency (Handovsky, Underhill). Furthermore, it is a reliable cellular stimulant (Handovsky). Another indication for the use of iron and copper is formed by hyperthyrosis (Hesse, Carpus and Zeppmeisel).

Another important therapeutic factor in parodontosis is liver (Boenheim, 1929). I like to combine iron, copper and liver, and have been using it in the form of "Heptogene" which contains iron, copper, liver, vitamin B and calcium. I have used this preparation during the last 6 months in all of my parodontotic cases, and the results have been very satisfactory. Since this particular therapy of parodontosis is unknown, as yet, 2 case reports which are apt to serve as illustrations of my form of treatment of parodontosis and anemia associated with disorders of the thyroid gland are given:

H. C., white female, 41 years of age. The patient had been operated upon for an ovarian cyst, 4 years previous to examination. General condition: Constipation, irregular menstruation, lasting for one to one and a half days, weakness, marked loss of hair, rather irritable and nervous. The patient is a tall woman, showing an absence of fat, especially on the thighs. The thyroid gland is not enlarged, the internal organs are in good order. Blood pressure: 90:60, Wassermann: negative, basal metabolic rate: 5, specific dynamic

action after 2 hours: plus 10, Ca: 11.8 mg. per cent, P: 3.3, K: 190. Hb: 70, 54 poly, 38 lymph., 8 monoc. (percentage).

Typical parodontosis, treated for years by the patient's dentist.

Diagnosis: hypophyseal emaciation.

Therapy: "Heptogene," 3 times a day, 2 tabl., and hypophyseal medication. Also dietetic directions.

The nervousness vanished completely after 8 weeks. The patient gained 12 lbs. in weight. After 8 weeks the Hb. was 88. The patient was sent back to her dentist who stated that "the condition of the teeth had greatly improved; her gums are hard and firm, and have a much better color. Patient is now able to brush her teeth without the former great flow of blood."

The other case refers to a severe thyroid condition: M. T., white female, 50 years of age. General condition: Pat. has been suffering from exopthalmic goitre since her 16th year of life. Typical symptoms: tachycardia (102), goiter, exophthalmus, increased basal metabolic rate (plus 34 per cent). Various nervous symptoms, such as profuse perspiration, loss of hair, diarrhoea. The patient also shows a severe parodontosis. Erythrocytes: 2,950,000. Hb: 54. Operation is refused by the patient.

Diagnosis: Graves' disease associated with severe parodontosis.

Therapy: Galvanization of the thyroid gland and thymus. "Heptogene," 2 tablets 3 times daily.

After 10 weeks the patient declared to be wholly free from nervous symptoms. Basal metabolic rate: plus 18. Pulse rate: 80. Erythrocytes: 3,830,000, Hb: 85. The dentist informed me that the vulnerability of the gums had completely vanished; the gums that had been badly discolored, had again a healthy red coloration. The local treatment of the parodontosis was now much facilitated.

Several authors, such as Sachs and Frohman, stress the importance of mental factors in the treatment of parodontosis.

SUMMARY

The mere fact, that I have, so far, treated approximately 500 cases of parodontosis in cooperation with the dentist, does not permit arriving at final conclusions. This one conclusion may be safely drawn: the general practitioner should assist the dentist in his anti-parodontosis treatment by administering the proper general treatment. Thereby, the work done by the dentist will be greatly facilitated. The modern treatment of parodontosis definitely requires full cooperation between dentist and physician—local treatment plus general treatment.

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DOES RESECTION OF THE NERVES SUPPLYING THE MANDIBLE AFFECT TOOTH DEVELOPMENT?[1]

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A review of the literature reveals that relatively little attention had been paid to the problem concerning the effect either of traumatic or experimental resection of the nerves supplying the maxilla or mandible on the development or eruption of teeth. Vieyra (4) reported that unilateral extirpation of the superior cervical sympathetic ganglion in dogs operated 7–12 days after birth resulted in retardation in development of the mandibular teeth on the operated side. This author mentions, without citing any references, that Angelucci observed the same effect in dogs, that Nemzoglau on the other hand noted an acceleration in the development of the teeth whereas Hertel observed no alteration in the rate of growth of the teeth in young rabbits. King (3) found (a) that unilateral resection of the inferior alveolar (dental) nerve in young dogs resulted in a slight acceleration in eruption of the permanent teeth on the operated side; (b) that a similar operation on rabbits resulted in acceleration of growth of the permanently growing incisor tooth on the operated side, at least during the first 8–21 days following the operation after which time a slight retardation in rate sometimes occurred and (c) that unilateral extirpation of the superior cervical ganglion in rabbits likewise produced an increased rate of growth of the lower incisor tooth on the operated side.

The objective in the present study was to determine whether or not unilateral resection of the nerves supplying the mandible of the kitten affects the development of the permanent tooth-germs. Three series of operations were performed using 2 animals of the same age in each series. In the first series the superior cervical sympathetic

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ganglion was resected on the right side; in the second series the superior cervical ganglion and the inferior alveolar nerve were resected on the same side and in the third series unilateral resection of the inferior alveolar nerve only was performed. All operations were done aseptically under ether anesthesia. With a single exception the animals remained free of postoperative infection.

The inferior alveolar nerve was approached through an incision in the skin along the inferior border of the mandible at about the level of the angle. The internal pterygoid

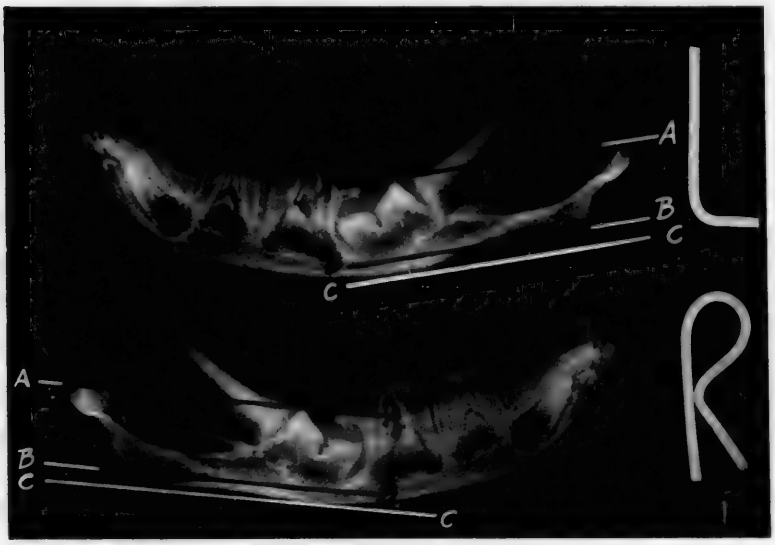


Fig. 1. Photographic enlargement of roentgenograph of 2 halves of mandible of kitten 46. R, right or operated half; L, left or control half; AA, line through tip of highest cusp of molar tooth-germ; BB, line through the lowest point on the base of the tooth-crypt and CC, line through inferior border of mandible.

muscle was carefully detached from its insertion exposing the inferior alveolar nerve and vessels at their entrance into the mandibular foramen. These were separated so as to avoid injury to the vessels and the nerve was resected at the point where it entered the foramen. The superior cervical sympathetic ganglion was approached through a longitudinal incision along the ventrolateral aspect of the neck near the base of the skull. The success of these operations was verified by post-mortem examination.

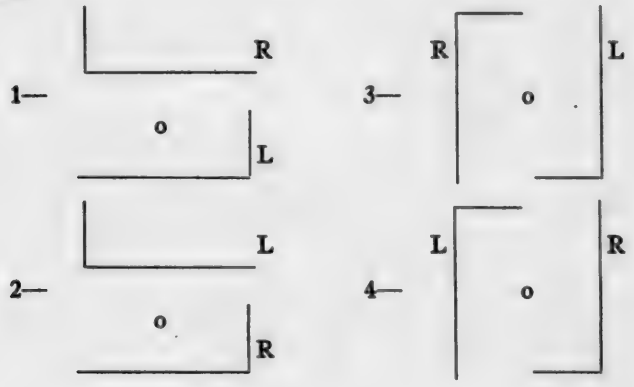
The methods employed to determine the effect of the 3 series of operations on the development of the permanent tooth-germs of the mandible were as follows: The animals were cancelled 7–21 (2)–22–23 or 38 days after operation. The mandibles were removed, cleaned of all muscles, divided at the symphysis into halves and both halves roentgenographed. Two parallel lines were drawn through the tooth-germs of the permanent lat-

eral incisor, canine, first and second premolar and molar teeth of both halves of the mandibles on the roentgenographs. One of the lines was drawn through the tip of the highest cusp and the other through the lowest point on the base of the tooth-crypt. The size of the tooth-germs was determined by measuring the distance between these parallel lines by means of a vernier caliper.

In order to verify the results obtained by the above procedure photographic enlargements of the roentgenographs were made and the size of the enlarged molar tooth-germs was determined in the same manner (*fig. 1, A and B*). As a further verification of the findings relative to the amount of growth undergone by the molar tooth-germs a third parallel line was drawn on the photographic enlargements passing through the inferior border of the mandible (*fig. 1, C*). The distance between the upper (A) and lowest (C) line was measured and may be interpreted as the amount of growth undergone by the tooth-germ.

The unoperated (left) side of each mandible was used as a control. Moreover the same procedures, as outlined above, were employed in determining the size of the tooth-germs on both halves of the mandible of an unoperated or normal kitten of the same age as kittens 45 and 46 (2–6–'37). The vernier caliper used in measuring the tooth-germs was calibrated in millimeters and the ends of the measuring arms were sharpened in order to secure greater accuracy. All measurements were made under magnification with the use of a binocular lupe. Furthermore all recorded measurements shown in the accompanying tables represent the average or arithmetical mean of 10 measurements, the object being to secure as great a degree of accuracy as possible.

The precautions taken to avoid distortion in the roentgenographs were as follows: 1) All exposures were made with a distance of 8 cm. from the tube to the film. 2) The same time of exposure, one second, was used in all cases. 3) The tube was in a perpendicular position and was centered over the film (occlusal dental film) in all cases. 4) The half mandibles were arranged equidistant from the film center in all cases. 5) As a check on the accurary of this technique the following variation of relative positions of one pair of mandible-halves was used:



As a result of the measurement of the shadows of different tooth-germs of the pair of mandible halves in the 4 variations of position shown above the relationship between the measurements was found to be the same, regardless of arrangment. Such a test demonstrates the possibility of arranging the material to avoid distortion and consequent inaccuracies in measurements. It will be noted that in comparisons of roentgenographs of right and left sides, operated and control conditions, these 2 halves occupied the same film which automatically equalized exposure time and tube distance. This left the only possibilities of variation to be in the centering of the tube over the film and the placing of the 2 mandible halves equidistant from the central ray from the tube. Extreme care was taken to meet these conditions.

Precautions were also taken during the operative procedures to avoid injury to adjacent blood-vessels and to thus eliminate the possibility of vascular injury which might interfere with results. The fact that the results obtained from the first 2 series of operations differed from those of the third series likewise precludes the possibility of interference of operative trauma.

The mandibles were decalcified in nitric acid and histological preparations made for microscopic examination.

The effect of the 3 series of operations on the size of the permanent tooth-germs of the operated (op) and control (con) sides of the mandibles as shown in the roentgenographs can be seen in *Table 1*. A detailed analysis of these findings need not be dwelt upon here. Suffice it to emphasize the striking consistency in the acceleration of growth of the tooth-germs on the operated side of the mandibles of those kittens in which the superior cervical ganglion was resected (numbers 34–36–35 and 37). This fact is brought out by the percentage difference in size (%) of the mean ($\bar{X}$) values.

Moreover, attention is called to the inconsistency of results in the third series of operations (animals #45 and 46). It will be noted that the mean difference in size of tooth-germs between the operated and control sides of the mandible is greater in the case of the second incisor, II premolar and molar teeth only. In short the tooth-germs in this series are larger on the operated side in only 60 per cent of the cases as compared to 100 per cent of the cases in the other 2 series. That

the increased size of the 3 tooth-germs in this series may be attributed to normal variation in size between tooth-germs rather than to the effect of resecting the inferior alveolar nerve could be inferred from the measurements of the tooth-germs in both halves of the mandible of the unoperated or normal kitten (#44). The fact is brought out in the table that in the latter animal 60 per cent of the tooth-germs on the left side of the mandible, which corresponds to the normal or unoperated side in the series of operated animals, are larger than those on the right side, showing that variation in size of corresponding tooth-germs in both halves of a mandible may be expected normally. Obviously the conclusion cannot be drawn that 60 per cent of the tooth-germs on the left side of the mandible of all normal, unoperated kittens are larger than the corresponding tooth-germs on the right side of the mandible. However the measurements of the tooth-germs in this particular case tend to substantiate the results obtained from severing the post-ganglionic sympathetic fibers on the size of the tooth-germs in animals 34–36–35 and 37, whereas, the results obtained from severing the inferior alveolar nerve on the size of the tooth-germs in animals 45 and 46 are doubtful or are at least inconsistent.

The measurements of the molar tooth-germs on photographic enlargements of the roentgenographs (*fig. 1*) are given in Table II, in which can be seen that the results shown in Table I, concerning the effect of resecting the superior cervical ganglion on the size of the tooth-germs, are confirmed, namely that there is an acceleration in growth on the operated side of the mandible in comparison with the unoperated side. In regard to the effect of resecting the inferior alveolar nerve the results shown here are again doubtful, since the enlarged molar tooth-germs are only 1 per cent larger on the operated as compared to those on the unoperated side. In the control animal the molar tooth-germ on the left side is (8 per cent) larger than on the right side this again tending to verify the results obtained in the first 2 series of operations.

The distance from the tip of the highest cusp of each molar tooth-germ to the inferior border of the mandible as obtained from measurements of photographic enlargements (*fig. 1*) are also shown in Table II. The results verify the findings previously discussed, with the exception that the percentage difference between the mean values

for the operated and left sides of the mandibles from animals 45 and 46 is greater than shown in Table I or in the first column of Table II. This figure, however, may not be considered significant, since it is

TABLE I

Size of tooth-germs in roentgenographs

NO.	OPERATED	CANCELLED	SEC. INCIS.		CANINE		I PREMOLAR		II PREMOLAR		MOLAR	
			Op	Con	Op	Con	Op	Con	Op	Con	Op	Con
34	7–10–'36 Sup. Cerv.	7–31–'36	2.334	2.000	7.000	6.800	4.128	3.862	4.352	4.225	6.318	6.210
36	7–14–'36 Sup. Cerv.	7–21–'36	1.794	1.514	6.518	6.428	3.592	3.494	4.174	3.834	6.208	5.554
$\bar{X}$			2.064	1.757	6.759	6.609	3.860	3.678	4.263	4.029	6.263	5.882
%			15		3		5		6		7	
35	7–13–'36 Inf. Alv.	8– 5–'36										
	7–22–'36 Sup. Cerv.		2.580	2.360	8.000	7.882	4.308	4.158	4.160	4.080	6.500	6.200
37	8–18–'36 Sup. Cerv.	9–26–'36										
	8–28–'36 Inf. Alv.		4.440	4.384	9.500	9.442	5.504	5.344	5.580	5.000	8.360	7.559
$\bar{X}$			3.510	3.372	8.750	8.662	4.906	4.751	4.870	4.540	7.430	6.879
%			4		2		4		7		8	
45	2– 6–'37 Inf. Alv.	2–28–'37	1.842	1.860	7.592	7.746	4.160	4.248	4.726	4.506	6.650	6.535
46	2– 7–'37 Inf. Alv.	2–28–'37	2.450	2.140	7.384	7.362	3.960	4.200	4.510	4.696	6.780	6.662
$\bar{X}$			2.146	2.000	7.448	7.554	4.060	4.224	4.618	4.601	6.715	6.598
%			7			2		4	1		2	
44	Normal	2– 6–'37	1.878	1.712	5.962	5.870	2.818	2.862	3.846	3.924	6.002	6.390
%			9		2			2		2		7

questionable whether or not resecting the inferior alveolar nerve really has an effect on the size of the tooth-germs.

Histological examination of the mandibles obtained from these kittens failed to reveal any noticeable difference in structure between the tooth-germs on the operated side as compared with those of

the unoperated or normal side. King (3) claimed to have found marked evidence of increased vascularity of the teeth and surrounding tissues on the operated sides of the mandibles in his animals. However, no such change could be observed with any degree of certainty in the material obtained from the animals used in this study.

Naturally the question arises as to the probable explanation of the data obtained in this study. It is quite likely, as King held, that section of the superior cervical ganglion results in increased vascularity of the tooth-germs which in turn furnishes more nourishment and

TABLE II

Size of molar tooth germs as measured from enlarged photographs

NO.	TIP OF CUSP TO BASE OF CRYPT		TIP OF CUSP TO INF. BORDER MANDIBLE	
	Operated	Control	Operated	Control
34	16.32 mm.	16.12 mm.	18.68 mm.	18.44 mm.
36	15.84	14.62	18.32	17.00
$\bar{X}$	16.08	15.37	18.50	17.72
% diff.	5		5	
35	17.24	16.60	19.76	19.46
37	20.74	19.19	23.72	23.10
$\bar{X}$	18.99	17.89	21.74	21.28
% diff.	6		3	
45	17.52	17.28	20.52	19.91
46	16.93	16.86	20.62	20.18
$\bar{X}$	17.22	17.07	20.59	20.04
% diff.	1		3	
44	R—15.00	L—15.08	R—17.34	L—17.62
% diff.		1		2

hence stimulates more rapid growth. That sympathectomy would produce increased vascularity is explained on the basis that resection of the post-ganglionic, sympathetic fibers results in vasodilation, since these fibers when intact function normally as vasoconstrictors. Cessation of vasoconstrictor impulses to the vessels supplying the tooth-germs would therefore produce vasodilation of these vessels.

The results obtained from resecting the inferior alveolar nerve raises the question as to whether or not any vasoconstrictor fibers are involved. Various workers, notably Allen (1), Brashear (2) and

Windle (5), have described this nerve as composed of myelinated (general somatic) afferent fibers which conduct general sensory (touch and pressure) impulses from the teeth and periodontal tissues to the brain and of amyelinated fibers (about 20 per cent), the cell bodies of which are located in the trigeminal (Gasserian) ganglion. The latter fibers are said to conduct pain impulses and since their cell bodies are located in the ganglion of the trigeminal nerve they would therefore be excluded as being sympathetic (visceral efferent) fibers.

As was mentioned previously, King claimed that acceleration of growth of the teeth results from resecting the inferior alveolar nerve as well as the superior cervical ganglion. This author made the statement that "it appears, however, unlikely that destruction of the sensory fibers of the inferior dental nerve would accelerate tooth growth," In order to account for his results he therefore assumed "that the effects produced by resection of the inferior dental nerve in both dogs and rabbits were caused by the unintentional severing of vaso-constrictor fibers in very close association with, and probably within the actual sheath of, the sensory nerve." As far as the writers are aware the presence of sympathetic (vaso-constrictor) fibers have not been demonstrated in the inferior alveolar nerve of any animal including man. According to the description in the modern editions of Human Anatomy and Neurology texts post-ganglionic, sympathetic fibers from the superior cervical ganglion are distributed to the head by way of many of the blood-vessels of the head. If this explanation is true it should be possible to demonstrate by appropriate histological staining technique the presence of a sympathetic plexus on these vessels. Microscopic examination of the inferior alveolar artery, which was treated according to a modified Ranvier's gold chloride method, was made and the presence of amyelinated fibers was observed in the tunica adventitia. These fibers are probably vaso-constrictor or sympathetic fibers, the cell bodies of which are located in the superior cervical ganglion. It is likely, therefore, that resection of the inferior alveolar nerve alone would not exclude all of the sympathetic fibers which enter the mandibular canal regardless of whether or not any such fibers are contained within the sheath of that nerve. The existence of sympathetic fibers on the inferior alveolar artery may explain why growth of the permanent tooth-germs was not accelerated

consistently in those cases in this study where the inferior alveolar nerve alone was resected.

CONCLUSIONS

The conclusions arrived at from this study are: (1) resection of the superior cervical ganglion resulted in 100 per cent of the cases in acceleration of growth of all the permanent tooth-germs on the operated side; (2) resection of the inferior alveolar nerve alone yielded inconsistent results, only 60 per cent of the tooth-germs on the operated side showing increased rate of growth; (3) the increased rate of growth resulting from resection of the inferior alveolar nerve may be apparent rather than real and attributed to normal variation in the rate of growth of tooth-germs on the two halves of the mandible, since a study of the size of tooth-germs of a normal kitten reveals that 60 per cent of them are larger on one side than on the other; (4) acceleration in the rate of growth of tooth-germs following resection of the superior cervical ganglion may be explained on the basis of an increased vascularity due to vasodilation of the vessels which supply the future permanent teeth and surrounding tissues and (5) the inconsistent results obtained from resecting the inferior alveolar nerve only may possibly be attributed to the lack of vaso-constrictor sympathetic fibers within the nerve.

SUMMARY

1. The objective in the present study was to determine whether or not unilateral resection of the nerves supplying the mandible of the kitten affects the development of the permanent tooth-germs. 2. Three series of unilateral operations were performed, 2 animals of the same age being used in each series. The first involved resection of the superior cervical ganglion, the second resection of the superior cervical ganglion including the inferior alveolar nerve and the third involving the inferior alveolar nerve only. 3. The methods employed to determine the effect of these operations on the development of the permanent tooth-germs were (1) measurement of the length of the tooth-germs on roentgenographs by means of a vernier caliper, (2) repeating the same procedure by using photographic enlargements of the roentgenographs in order to verify the results obtained with

the first method and (3) determining the amount of growth exhibited by the molar tooth-germs in photographic enlargements by measuring the distance from the apex of the highest cusp to the inferior border of the mandible. 4. The unoperated side or half of each mandible was used as a control for each series of operations and in addition the mandible from an unoperated kitten of the same age as 45 and 46 served as a normal control. 5. In all cases where the superior cervical ganglion was resected 100 per cent of the tooth-germs which were measured on the operated side exhibited acceleration of growth, the average percentile difference in size of the tooth-germs being 6.1 per cent. 6. In the 2 animals in which the inferior alveolar nerve alone was resected only 60 per cent of the tooth-germs on the operated side exhibited acceleration of growth, the average percentile difference in size of the tooth-germs being only 3.2 per cent. 7. Measurements of the molar tooth-germs as well as the distance from the tip of the cusps to the inferior border of the mandible on photographic enlargements of the roentgenographs verify in general the results obtained from the roentgenographs. 8. The suggestion is offered that acceleration of growth of the tooth-germs on the operated side following resection of the superior cervical ganglion is due to increased vascularity resulting from vasodilation of the vessels which nourish the future teeth and surrounding tissues. 9. Failure to obtain consistent results following resection of the inferior alveolar nerve may be explained on the basis that few if any sympathetic, vaso-constrictor fibers are present in this nerve. It is suggested, moreover, that the apparent acceleration of growth in 60 per cent of the tooth-germs on the operated side following this operation may be attributed to a normal variation in growth rate since 60 per cent of the mandibular tooth-germs of a normal kitten are larger on one side than on the other.

The authors wish to acknowledge valuable assistance rendered by Mr. Lowell E. McKelvey in the course of this study.

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DIMENSIONAL AND POSITIONAL VARIATIONS OF THE RAMUS OF THE MANDIBLE[1]

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Following the introduction of block anesthesia for the inferior alveolar nerve there were many reported failures of the procedure. Many communications tended to emphasize its dangers and described it as difficult and complicated. Communications about the danger of lingular block anesthesia, more commonly known as mandibular block anesthesia, appear even now, especially in American literature, when inhalation anesthesia is recommended as safer. We consider block anesthesia no more perilous than local infiltration anesthesia or any other intervention in connection with wounds.

G. Fischer gave the classical description of the procedure and the eventual failures and complications encountered by early users of his technique were said to result from imperfections in the method. Several recent contributions by various authors have recommended different, more or less correct, modifications to improve the original method. Levitt (1929) went so far as to declare plainly that the principal cause of failure was not to be sought in improper application of Fischer's technique, but in this technique itself. It is not our intention to argue against Levitt but we mention that Levitt's own method has as many possible sources of failure as has that of Fischer because both lay down rigorous rules allowing very little choice for individual judgment.

The essential differences between the methods of various authors refer to: 1) place and level of injection, 2) direction of the needle, 3) method of the needle's penetration. Most authors, (Fischer, Braun, Willinger, Seidel), give the place of injection somewhat mesially from the temporal crest at a height of ¾ to 1 cm., or a finger's breadth, above the masticating surfaces of the mandibular molars.

[1] Presented at the 15th General Meeting of the International Association for Dental Research, Baltimore, March 13 and 14, 1937.

Levitt and Schleich, on the other hand, inject at a point bisecting the distance between the masticating surfaces of the maxillary and mandibular molars and laterally from the pterygomandibular ligament. The direction of the syringe is determined differently by nearly every author; Fischer indicating the canine of the opposite side, Levitt the first premolar, Willinger the second premolar or first molar, Braun and Schleich the region of the corner of the mouth of the opposite side and Seidel the line parallel to the same side but mesial to the corner of the mouth. As to the needle's direction, most authors believe that the bone path is proper, contrary to Levitt and Willinger who recommend the direct approach to the lingula. It is extremely difficult to judge which method is correct on the disputed points because good results and a certain percentage of failures are obtained with every method. None of the methods are bad; neither are any of them perfect, none of them affording good results with absolute certainty even when the prescribed technique is followed most exactly. It must always be considered that individual anatomical variations may be the cause of these imperfections in the methods. We purpose to investigate the quality, dimensions and frequency of these variations.

In the course of previous dissections, made for other purposes, we noted that the dimension of the attachment surface of the internal pterygoid muscle was subject to extraordinarily large variations. This is of particular importance because this muscle limits one side of the pterygomandibular space wherein the solution is deposited. If this attachment is extended and elevated the needle may get into the fibers of the internal pterygoid muscle, instead of the space, when the height of injection is guided by the masticating surface of the mandibular molars. This will prevent closure of the mouth or produce difficulty and pain on opening the mouth, a condition sometimes lasting several days.

Another source of error originates from fixing the depth of penetration of the needle. G. Fischer designated 15 mm. as the depth of penetration and considered this so constant a value that he soldered a small ball on the needle at this point as an obstacle to deeper injection. This value is supposed to correspond to the distance to the lingula, i.e., from the sulcus to the temporal crest. This only exists when the lingula is in the midline of the ascending ramus and can only be con-

stant when the width of the ramus is constant or approximately constant. For this reason our investigation was directed toward establishment of median values for the width of the ascending ramus.

The line of direction of injection, given differently by nearly every author, is important in those methods using the bone path to the lingula. Seidel is the only author who notes that the angle formed by the inner surface of the ascending ramus and the median plane is subject to individual variations. Although we do not agree with his method we find his conclusion, disregarded by later authors, of some value, viz., that the angle formed by the ascending ramus and the median line varies individually.

We believe that any method which disregards the possibilities of variation cannot be perfect. However, if we take into consideration these variations we must, because of their frequency, disregard rigorous rules as it is strict adherence to these rules that leads to failure in those cases showing variations. Measurements made on the material at our disposal show the dimensions and frequency of such variations in the mandible. Only the general remarks of Seidel suggest these variations. *First*, the width of the ascending ramus of the mandible, of decisive importance in determining the distance of the lingula from the temporal crest and thus depth of penetration, was investigated. *Second*, the inclination angle of the ascending ramus with the median line, which allows approach to the inner surface and thus to the pterygomandibular space, was studied. This important area is the point where the solution should be deposited. The only correct direction for injection by bone-conduct is that which coincides with the direction line of the inner surface of the ascending ramus. *Third*, the shortest distance between the highest point of the retromolar triangle and the interincisal point was measured. This distance is the greatest radius of the arc of the mandibular process of the mandible. This measurement was necessary to determine whether there is a correlation between the depth of the alveolar arc and the width of the ascending ramus which might give information concerning the approximate position of the lingula in the horizontal plane and also to determine if there is a leveling correlation between the length of the mandible and the inclination angle between the ascending ramus and the median plane. Were this so, from the depth of the alveolar arc which

is readily determined on the living, the inclination angle between the ramus and the median plane could be derived. This information is necessary to determine the direction of injection for each individual. *Fourth*, the entire length of the ascending ramus was measured and, on the same mandibles, the distance from the margin of the mandible to the anterior root of the lingula was determined. For the entire length of the body of the ramus the smallest distance which could be measured between the margin of the mandible and the deepest point of the sigmoid notch was taken. By proportioning these two values,

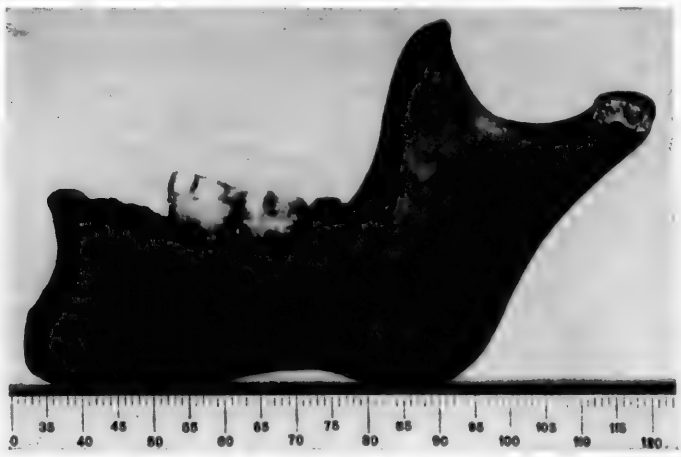


Fig. 1. Mandible of Italian woman, age 35. Width of ramus —26 mm.

i.e., the entire length of the ramus and the distance from the margin of the mandible to the anterior root of the lingula, the possible vertical variation of the normal position of the lingula, usually described as the center of the ramus, was ascertained. This is important in determining the height of injection.

Seven hundred and fifty mandibles were examined, 500 from individuals of the same epoch and admissibly of homogeneous race[2] and 250 from individuals from different parts of the world, of different races and ages.[3] Measurements for examination I and II were made

[2] From the Christian Cemetery of Budapest, closed 1850. Collection of the Anthropological Institute.

[3] Collection of the Anatomical Institute.

separately on the 500 mandibles of homogeneous and 250 mandibles of heterogeneous origin. The mandibular dimensions of the two groups were compared to determine the coincidence or convergence of the median values and the direction and degree of divergence from the average values. The measurements of examination III were made on the 500 homogeneous mandibles and for examination IV on the 250 heterogeneous mandibles.

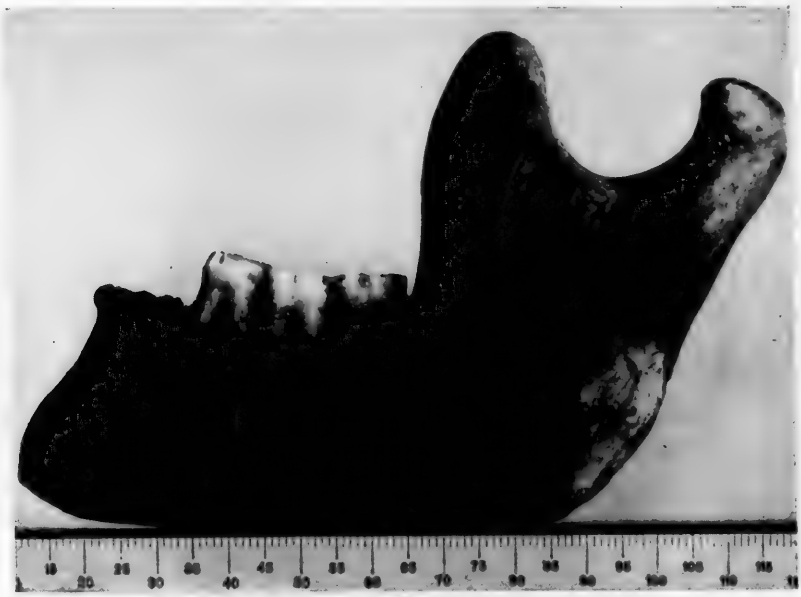


Fig. 2. Mandible of man of East Siberia, age 28. Width of ramus —38 mm.

WIDTH OF ASCENDING RAMUS

Fig. 1 shows the mandible of an Italian woman, age 35, with an ascending ramus 26 mm. wide. *Fig. 2* shows the mandible of a 28 year old man of East Siberia with a ramus 38 mm. wide. The smallest width measured by us was 22 mm., the largest 44 mm. (skulls from New Caledonia). Ascending rami of similar extreme widths were found on Mongolian (38 mm.), Sudanese (40 and 40.5 mm.) and Greenland (41 mm.) skulls. The variations of the ascending ramus, aside

from width, which must be considered can be concluded from study of *figs. 3* to *8*, radiographs of different types of rami. It was found that the line of smallest width met the lingula in every instance.

The results of these measurements point to 3 important facts:— 1) The variations are much greater than could be concluded from the anatomical descriptions of the mandible; 2) The variations are essentially greater in the heterogeneous material than in the Hungarian skulls; 3) While in the heterogeneous material the deviation from the median values is greater toward the larger values the deviation in the homogeneous material is toward the smaller values. The smallest

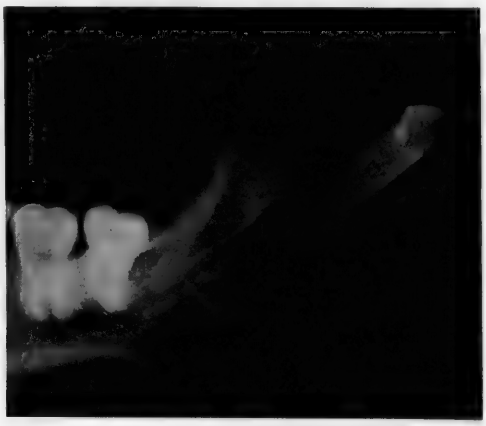


Fig. 3. Roentgenogram of ramus, 41 mm. long, 24 mm. broad

width of the ramus varied between 21 and 44 mm. in the heterogeneous, and between 20 and 39 mm. in the homogeneous mandibles. The quantitative median value was 30 mm. for both collections. The width of the ascending rami was between 29 and 31 mm. in 26.4 per cent of the heterogeneous mandibles and in 30 per cent of the homogeneous. Thus, if 29 to 31 mm. is taken as the normal median value, only one fourth of the heterogeneous and scarcely one third of the homogeneous material can be included therein. The remaining three fourths and two thirds, respectively, are broader or narrower. If we go further and disregard variations from the median not within 3 but within 9 mm., a highly inexact procedure, we still find only 66.4 per

Fig. 4. Roentgenogram of ramus, 47 mm. long, 36 mm. broad

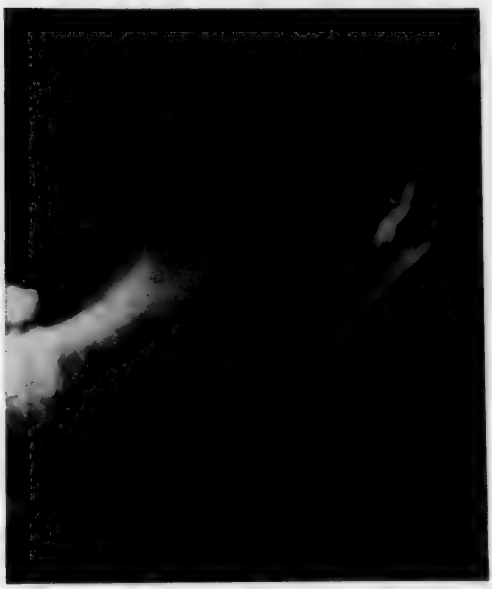


Fig. 5. Roentgenogram of ramus, 54 mm. long, 36 mm. broad

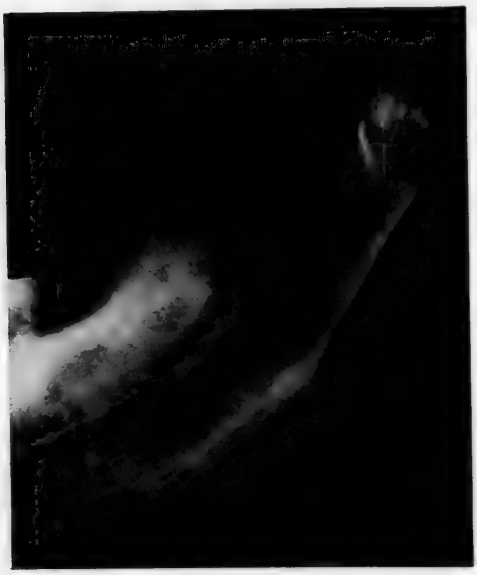


Fig. 6. Roentgenogram of ramus, 52 mm. long, 38 mm. broad

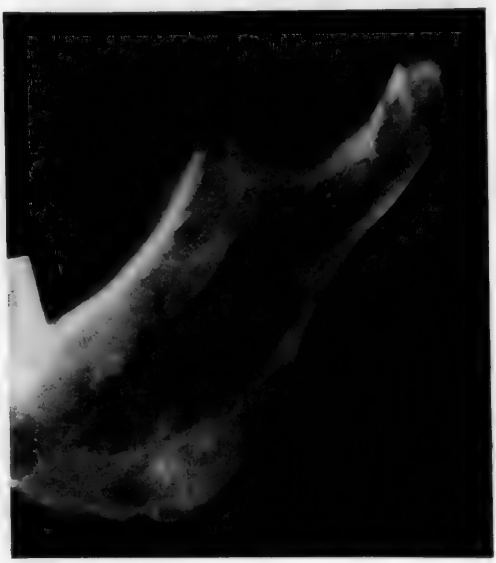


Fig. 7. Roentgenogram of ramus, 61 mm. long, 28 mm. broad

cent of the mandibles of heterogeneous origin and 85.4 per cent of those of homogeneous origin within the limits of 26 to 34 mm. One third of the heterogeneous and one fifth of the homogeneous mandibles will still fall outside of these wide limits. Four per cent of the heterogeneous and 8.8 per cent of the homogeneous mandibles were distributed between 20 and 25 mm., while 5.8 per cent of the homogene-

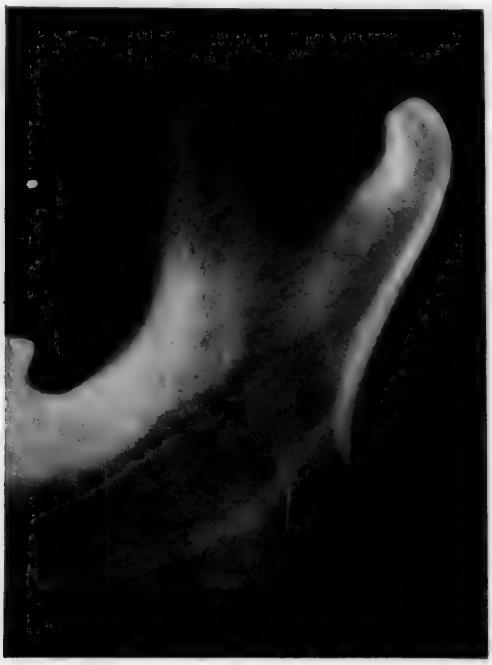


Fig. 8. Roentgenogram of ramus, 63 mm. long, 36 mm. broad

ous and 29.6 per cent of the heterogenous were distributed between 35 and 44 mm. in width of the ramus. Thus, while the width of the rami of mandibles of homogeneous origin differing from the median values is usually smaller, in the heterogenous material it is usually larger.

It follows from these figures, that in extreme cases the sulcus behind the lingula can be 10 mm. from the temporal crest (on a ramus 20

TABLE I

Width of ramus

Width (mm.)	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	S.
Homogeneous	1	2	2	10	9	20	25	57	67	38	67	49	62	42	20	14	6	7	1	1						500
Heterogeneous		1	1	1	1	6	11	13	10	17	27	22	23	21	22	24	17	17	6	4	3	1	1		1	250
Combined	1	3	3	11	10	26	36	70	77	55	94	71	85	63	42	38	23	24	7	5	3	1	1		1	750

TABLE II

Width of ramus (condensed)

Width (mm.)	20–22	23–25	26–28	29–31	32–34	35–37	38–40	41–44	S.
Homogeneous	5	39	149	154	124	27	2		500
Heterogeneous	2	8	34	66	66	58	13	3	250
Combined	7	47	183	220	190	85	15	3	750

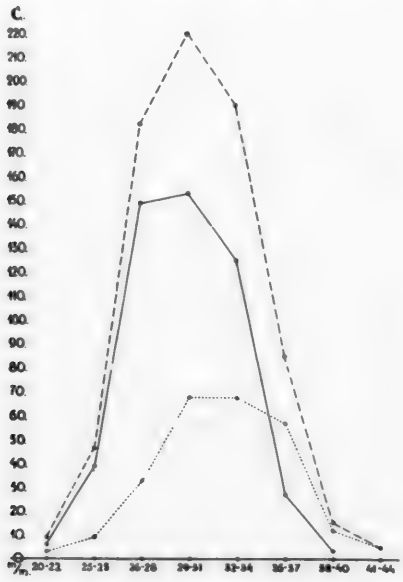


Fig. 9. Variation curve of widths of ramus. ——— homogeneous mandibles, ... heterogeneous mandibles, ---------- all mandibles. Vertical—number of cases (C), Horizontal—width in mm.

mm. wide) or 22 mm. away (on a ramus 44 mm. wide). At the depth of 15 mm., given by G. Fischer, the needle point can reach the correct place only on an ascending ramus 30 mm. wide. Such rami, 29 to 31

mm. wide, were found only in 26.4 and 30.4 per cent of the heterogeneous and homogeneous mandibles, respectively.

Table I gives the detailed results of the measurement of the width in the 750 ascending rami. In order to eliminate the variations of measurement the results of Table I have been contracted into groups of 3 mm. (Table II). These results are expressed diagrammatically in *fig. 9* and Table III gives the percentage distribution.

TABLE III

Width of ramus (per cent distribution)

	HOMOGENEOUS	HETEROGENEOUS	COMBINED
	(*per cent*)	(*per cent*)	(*per cent*)
Median value (26–31 mm.)	26.4	30.8	29.3
Extended median value (26–34 mm.)	85.4	66.4	79.0
Lower distribution (20–25 mm.)	8.8	4.0	7.2
Upper distribution (35–44 mm.)	5.8	29.6	13.8

Fig. 10. Approximately parallel rami

Fig. 11. Moderately diverging rami

Fig. 12. Strongly diverging rami

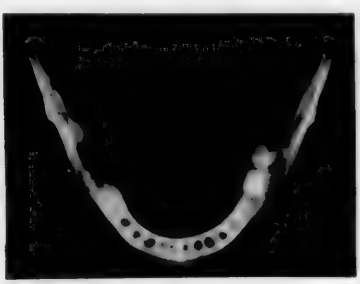


Fig. 13. Extremely diverging rami

INCLINATION ANGLE

The angle between the ramus and the median plane was measured and this inclination angle showed great differences in the material examined. If the mandibles in *figs. 10* and *11* are compared with

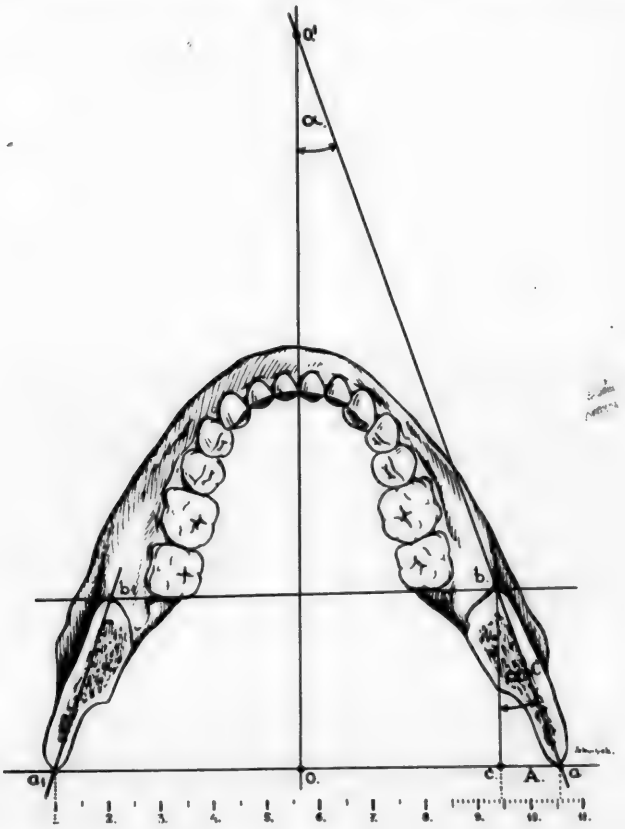


Fig. 14. aa_1—distance between posterior margins of rami, bb_1—distance between anterior margins, ab = C—smallest width of ramus, ac = A—half of difference of lines connecting anterior and posterior margins, 00_1—median plane, α—inclination angle.

those in *figs. 12* and *13* it can be seen without measuring that in the former illustrations the 2 rami are approximately parallel while in the latter the rami diverge widely. The inner surface of the ramus is

rendered rather uneven by the lingula, the mylohyoid sulcus and the root of the temporal crest, so that it is unsuitable for boniometric measurements. For this reason, the angle formed between the line connecting the most prominent points of the anterior and posterior margins of the ramus and the median plane is considerated the inclination angle of the ramus to the median plane. For calculation of this angle (α) the following information was needed:— 1) the narrowest width of the ramus, 2) the measurement of the posterior terminal points of the narrowest width projected upon the outer surface of the ramus and 3) the distance between the anterior terminal points. All of these are readily measurable on the mandible.

From these data we determined the inclination angle by means of trigonometric calculation; constructing a right-angle triangle, the base of which was given by half the difference of the distance between the anterior and posterior terminal points (A), and the hypotenuse by the smallest width of the ramus (C). Knowing the base (A) and the hypotenuse (C) the angle α opposite 'A', the inclination angle, could be calculated (*fig. 14*).

For example: the smallest width of the ramus illustrated in *fig. 1* is 26 mm. (C). The distance of the posterior terminal points of this width projected upon the outer surfaces of the 2 rami (aa_1) = 96.5 mm.; the distance between the anterior terminal points (bb_1) = 86 mm. Based on these data the hypotenuse of the right angle triangle to be constructed is C = 26 min., the base opposite the inclination angle is

$$A = \frac{aa_1 - bb_1}{2} = \frac{96.5 - 86}{2} = 5.25 \text{ mm.}$$

Therefore

$$\sin \alpha \frac{A}{C} = \frac{5.25}{26} = 0.20192$$

and the inclination angle (α) is 11°5′.

In measuring this angle it was observed that the variations were greater than would be assumed on the basis of anatomical knowledge. On the material examined the smallest value was 0° and the largest

27°. The quantitative average values were 13° and 10°, respectively, but the distribution was very much greater than with the measurements of the width of the ramus, indicating that we can rely even less on the inclination angle. It was further observed that although the distribution in both heterogeneous and homogeneous material was toward the lower values, in the homogeneous material the distribution toward the lower values was double that toward the upper and in the heterogeneous material the toward the lower values was 7 times greater than toward the upper. Since in measuring the width of the ramus contrary results were obtained, it is possible to think of a certain connection between the width and inclination angle of the ramus. The values are inversely proportional and, according to these results, a broader ramus corresponds to a smaller angle and a narrower ramus to a wider angle. As there is a very marked difference between the direction of distribution in the homogeneous and heterogeneous material it seems that in human groups of different races the average inclination angle varies.

TABLE IV

Inclination angle of ramus

Inclination angle (degrees)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	S.
Homogeneous	2	2	2	7	8	10	14	16	30	37	39	40	43	64	45	36	32	27	14	12	5	5	5	2	2	1	1	1	500
Heterogeneous	6	4	5	5	7	7	21	18	22	21	18	25	19	18	13	13	11	4	4	4	2	1		2					250
Combined	8	6	7	12	15	17	35	34	52	58	57	65	62	82	56	49	43	31	18	16	7	6	5	4	2	1	1	1	750

On the heterogeneous material the inclination angle varied between 0° and 23°, on the homogeneous between 0° and 27°. The average value for the heterogeneous material was 10°, for the homogeneous material 13°. As the inclination angle was found to lie between 12 and 14 in only 20 per cent of the homogeneous skulls and in only 30 per cent of the heterogeneous, accepting 12 to 14 degrees as the normal median value only one fifth and one third of the respective types can be considered within normal range. If a range of variation of 9 degrees is accepted, which is practically unallowable, we can still place only 56.8 per cent of the heterogeneous and 72.2 per cent of the homogeneous material within this category.

The lower distribution, from 0 to 8 degrees, occurs in 38 per cent of

the heterogeneous mandibles and in 18.2 per cent of the homogeneous. The upper distribution is found in 5.2 per cent of the heterogeneous and 9.6 per cent of the homogeneous jaws.

In methods attempting to direct the needle to the lingula by bone conduction it is intended that the needle should move in a direction

Fig. 15

Fig. 16

Fig. 15. **Mandible with rami of 13° inclination angle—average value**
Fig. 16. **Mandible with parallel rami, inclination angle of extreme lower limits—0°**

Fig. 17. **Mandible with strongly diverging rami, inclination angle of extreme upper limits—27°.**

parallel to the surface of the ramus. If the inclination angle of the ramus varies as indicated it is evident that only in a small percentage of cases will the needle move parallel to the ramus and then only by chance. In the majority of cases it will be at a more or less acute angle to the ramus (*figs. 15* to *17*). It is impossible to determine a generally valid line of direction for the injection.

TABLE V

Inclination angle of ramus (condensed)

Inclination angle (degrees)	0–2	3–5	6–8	9–11	12–14	15–17	18–20	21–23	24–27	S.
Homogeneous	6	25	60	116	150	95	31	12	5	500
Heterogeneous	15	19	61	64	50	28	10	3		250
Combined	21	44	121	180	200	123	41	15	5	750

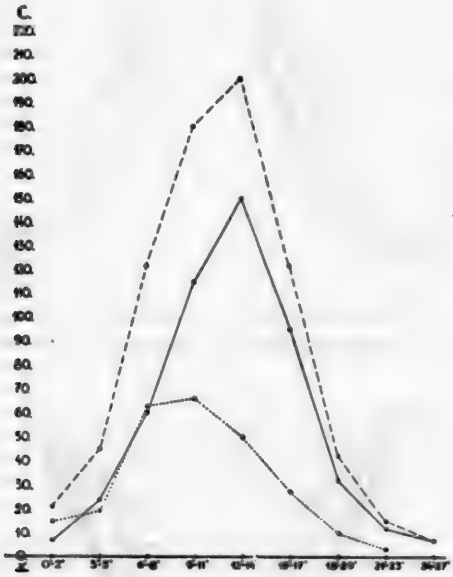


Fig. 18. Variation curves of inclination angle of ramus. ——— homogeneous mandibles, ... heterogeneous mandibles, ———— all mandibles. Vertical—number of cases (C), horizontal—inclination angle (degrees).

TABLE VI

Inclination angle (per cent distribution)

	HOMOGENEOUS (*per cent*)	HETEROGENEOUS (*per cent*)	COMBINED (*per cent*)
Median value (12–14 degrees)	30.0	20.0	26.6
Extended median value (9–17 degrees)	72.2	56.8	67.1
Lower distribution (0–8 degrees)	18.2	38.0	24.8
Higher distribution (18–27 degrees)	9.6	5.2	8.2

Table IV gives the detailed results of these measurements of the inclination angle of the ramus. To eliminate errors of measurement the results are contracted by arrangement in 3 groups. (Table V) Diagramatically the results are expressed in *fig. 18*. Table VI gives the percentage distribution.

DISTANCE BETWEEN RETROMOLAR TRIANGLE AND INTERINCISAL POINT

On the homogeneous material the shortest sagittal distance between the line connecting the anterior margins of the ramus and the interincisal point (contact point of mandibular first incisors) was measured. From this measurement the size of that part of the horizontal portion of the mandible which carries the dental arch can be determined.

TABLE VII

Sagittal distance

Sagittal distance (mm.)	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	S.
Number of cases	1	5	5	12	13	16	27	31	50	57	69	60	54	41	30	14	6	6	1	1		1	500

TABLE VIII

Sagittal distance (condensed)

Sagittal distance (mm.)	37–39	40–42	43–45	46–48	49–51	52–54	55–58	S.
Number of cases	11	41	108	186	125	26	3	500

This measurement was made in the hope that it might be correlated with either the width or inclination angle of the ramus. Such a correlation could not be established. With the comparatively short distance of 40 and 41 mm. rami from 21 to 35 mm. in width were found. On the other hand on mandibles 52 mm. long rami from 25 to 36 mm. in width were noted. The smallest sagittal distance was 37 mm., the largest was 58 mm. An attempt was also made to correlate the sagittal distance with the inclination angle without success.

The median value for the sagittal distance was 47 mm. In one third of the cases it varied between 46 and 48 mm. and in four fifths between 43 and 51 mm. The lower distribution of 37 to 42 mm. was approximately double that of the upper distribution (52–58 mm.). In Table VII the detailed results of these measurements are given. In Table

VIII the results have been grouped in series of 3 mm. to eliminate errors of measurement. Fig. 19 shows the results diagramatically.

On the basis of these measurements it can be stated that the distance of the interincisal point from the lingula varies between 54.5 and 93.5 mm. This result is obtained as follows: 1) The distance from

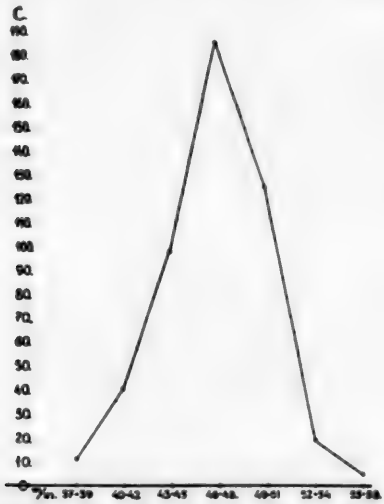


Fig. 19. Variation curve of sagital distance. Vertical—number of cases (C), horizontal—sagital measurement (mm.).

TABLE IX

Sagittal distance (per cent distribution)

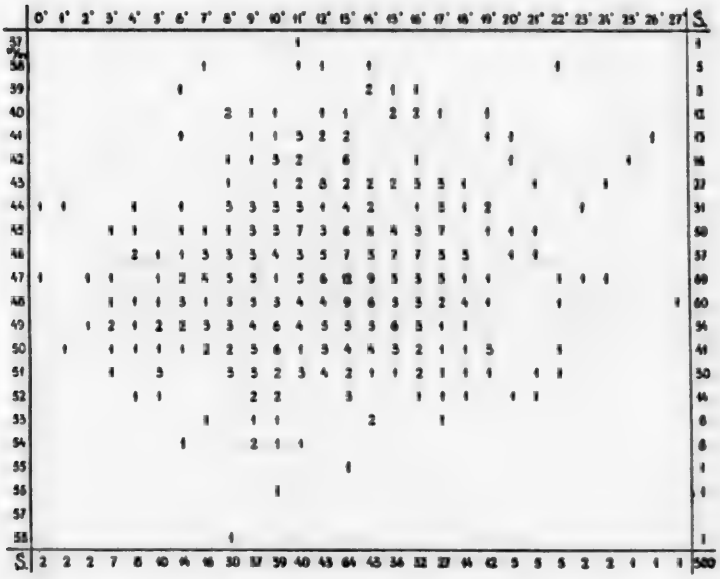
	per cent
Median value (46–48 mm.)	37.2
Extended average value (43–51 mm.)	83.8
Lower distribution (37–42 mm.)	10.4
Higher distribution (52–58 mm.)	5.8

the interincisal point to the anterior border of the ramus was measured in those jaws having the shortest (37 mm.) and longest (58 mm.) sagittal dimension and was found to be 49.5 and 71.5 mm. respectively. The average distance of the anterior margins of the rami from

each other was taken as 80 mm.; 2) Half the width of the smallest and largest rami were added to this ($49.5 + \frac{20}{2} = 54.5$ and $71.5 + \frac{44}{2} = 93.5$). In order to study distribution more thoroughly and to illustrate the above statement numerically the following dimensions have been coordinated with each other: width of the ramus, inclination angle and sagittal distance (obtained from homogeneous material).

TABLE X

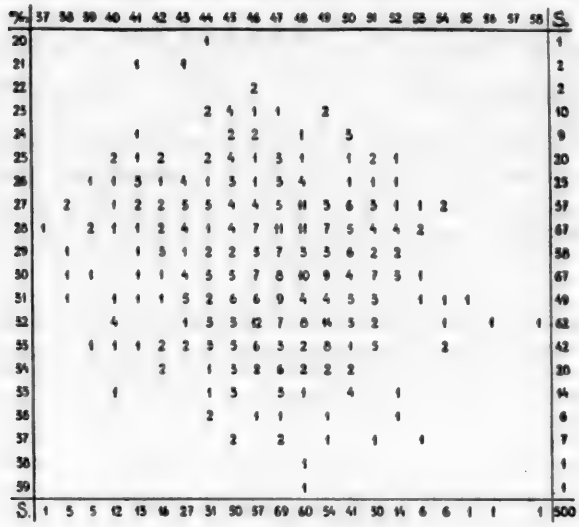
Sagittal distance (left vertical) vs. inclination angle (upper horizontal)



In Table X the sagittal distance is given on the left vertical line and the inclination angle on the horizontal line. In Table XI the width of the ramus is on the left vertical and the sagittal distance on the upper horizontal. In Table XII the width of the ramus (left vertical line) is compared with the inclination angle (upper horizontal line). In addition in Tables XIII and XIV the correlation of the inclination angle is expressed separately from the heterogeneous material and for the entire 750 mandibles.

TABLE XI

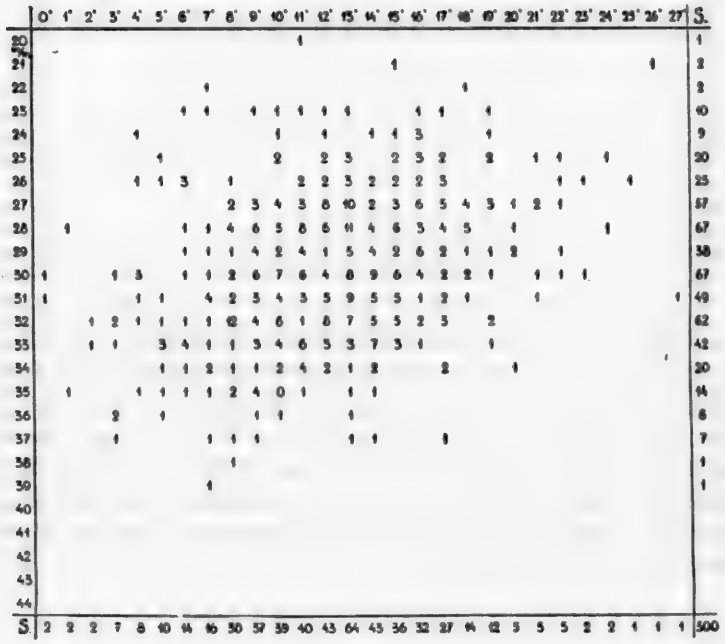
Sagittal distance (upper horizontal) vs. width of ramus (left vertical)



%	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	S.
20								1															1
21					1		1																2
22										2													2
23								2	4	1	1		2										10
24					1				2	2		1		3									9
25				2	1	2		2	4	1	3	1		1	2	1							20
26			1	1	3	1	4	1	3	1	3	4		1	1	1							25
27		2		1	2	2	5	5	4	4	5	11	3	6	3	1	1	2					57
28	1		2	1	1	2	4	1	4	7	11	11	7	5	4	4	2						67
29		1			1	3	1	2	2	3	7	3	3	6	2	2							56
30		1	1		1	1	4	5	3	7	8	10	9	4	7	3	1						67
31		1		1	1	1	5	2	6	6	9	4	4	5	3		1	1	1				49
32				4			1	5	3	12	7	8	14	3	2			1		1		1	62
33			1	1	1	2	2	3	3	6	3	2	8	1	3			2					42
34						2		1	3	2	6	2	2	2									20
35				1				1	3		5	1		4		1							14
36								2		1	1		1			1							6
37									2		2		1		1		1						7
38												1											1
39												1											1
S.	1	1	5	5	12	15	16	27	31	30	37	69	60	54	41	30	14	6	6	1	1	1	500

TABLE XII

Width of ramus (left vertical) vs. inclination angle (upper horizontal)



	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	S.
20												1																	1
21																													
22								1											1								1		2
23																1													2
24							1	1		1	1	1	1	1			1	1		1									10
25					1						1		1		1	1	3			1									9
26						1					2		2	3		2	3	2		2		1	1		1				20
27					1	1	3		1			2	2	3	2	2	2	3					1	1		1			25
28								2	3	4	3	8	6	10	2	3	6	5	4	3	1	2	1						57
29		1					1	1	4	6	5	8	6	11	4	6	3	4	5		1				1				67
30	1			1	3		1	1	1	1	4	2	4	1	5	4	2	6	2	1	1	2		1					38
31	1				1	1		1	2	6	7	6	4	8	9	6	4	2	2	1			1	1	1				67
32			1	2	1	1	1	4	2	3	4	3	5	9	5	5	1	2	1			1						1	49
33			1	1		3	1	1	12	4	6	1	8	7	5	5	2	3		2									62
34						1	1	1	1	3	4	6	5	3	7	3	1			1									42
35		1			1	1	1	1	2	1	2	4	2	1	2			2			1								20
36				2		1				1	1			1															14
37				1				1	1	1				1	1			1											6
38									1																				7
39								1																					1
40																													1
41																													
42																													
43																													
44																													
S.	2	2	2	7	8	10	14	16	30	37	39	40	43	64	45	36	32	27	14	12	5	5	5	2	2	1	1	1	500

TABLE XIII

Correlation of inclination angle with width of ramus (heterogeneous material)

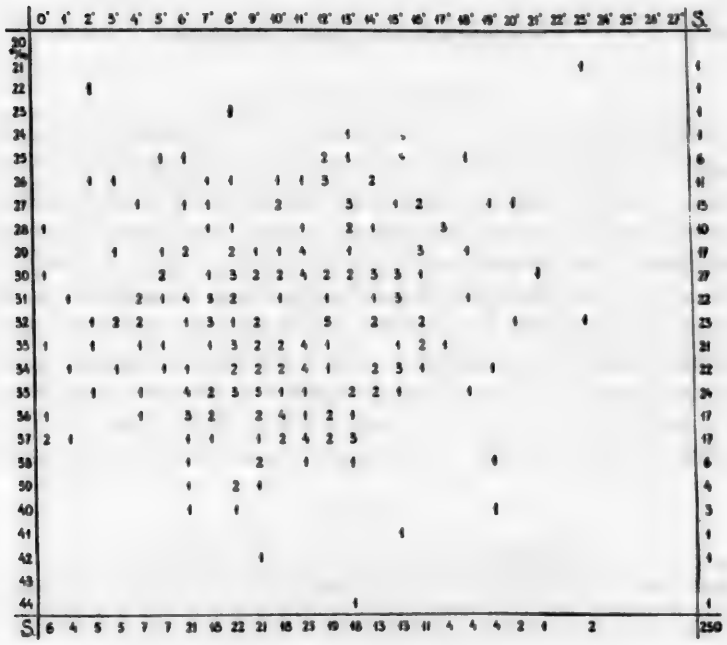
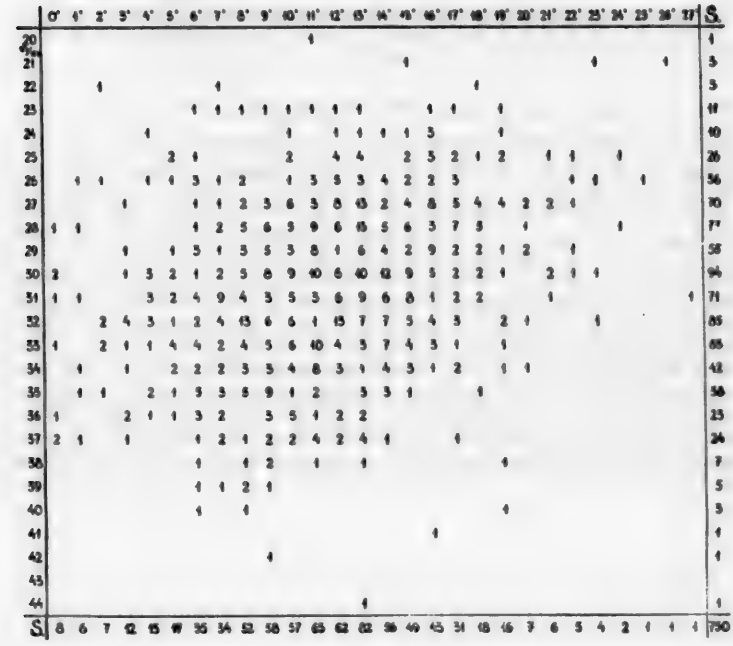


TABLE XIV

Correlation of inclination angle with width of ramus (combined material)



POSITION OF LINGULA

From the point of view of the block anesthesia is also important to know the relative position of the lingula on the inner surface of the ramus. To determine this position the distance from the lower border of the ramus to the lingula was measured on the 250 heterogeneous mandibles. The smallest distance was 15 mm., the largest 36 mm. Table XV gives the detailed results of these measurements. In Table XVI the results have been contracted into groups of 3 mm. to eliminate errors of measurement. These numbers, in themselves, do not express much and are of practical value only when the single values are correlated with the corresponding lengths of the rami. It does not influence the technique of injection if the lingula is at the midpoint

TABLE XV

Distance of lingula from inferior border of ramus

Distance (mm.)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	S.
Number of cases	2	1	4	6	14	16	22	21	23	20	29	21	13	9	11	15	10	5	2	1	3	2	250

TABLE XVI

Distance of lingula from interior border of ramus (condensed)

Distance (mm.)	16	17–19	20–22	23–25	26–28	29–31	32–34	35	S.
Number of cases	3	24	59	72	43	36	8	5	250

of the ramus but if on a ramus 50 mm. high we find the lingula at a height of 20 or 30 mm. the success of a stereotype technique will be influenced. Therefore the length of the ramus has been correlated with the distance of the lingula from the lower margin and the results have been expressed in per cents, for reasons of comparison, on the following basis: The length of the ramus is proportional to the distance from its lower margin to its lingula as 100 is to X. (X equals the division line, counted from below, on which the lingula is found.) In this way the height of the lingula is expressed in per cent independent of the different dimensions of the single rami and thus making it possible to compare the relative positions of the lingulae (*fig. 20*).

If on a 60 mm. long ramus the calculation gives a result of 50, this

means that the lingula is at a distance of $\frac{60 \times 50}{100} = 30$ mm. from the lower border of the ramus, i.e., exactly in the middle and corresponding to normal anatomical descriptions. As the middle of the ramus, the normal anatomical position, corresponds to the 50 per cent division line the smaller the number the lower the lingula and the larger the number the higher the lingula. The lower position of the lingula causes no difficulty in anesthesia because of the position of the pterygomandibular space but the higher position can easily lead to failure because the needle inserted for the normal position will not get

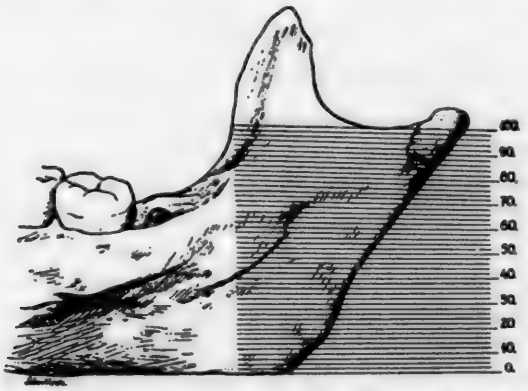


Fig. 20. Ramus divided into 100 parts. Lingula on division 58

into the space. It will pass between the fibers of the internal pterygoid muscle and only a small quantity of the anesthetic solution will diffuse to the inferior alveolar nerve.

As a result of these calculations the proportionate numbers found in Table XVII were obtained. In Table XVIII the numbers are contracted into groups of 3. The lingula was found in position 49 to 51, the normal, in only one fifth of the cases. Even by taking a divergence of 9 units (46 to 54) as normal variation only half of the cases fell within this class. In one eighth of the material the lingula was lower and in more than one third it was higher. Table XIX gives the per cent distribution.

TABLE XVII

Relative position of lingula

Proportionate number	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	S.
Number of cases	1		1	2		5	8	7	7	13	12	13	18	19	16	11	15	13	16	11	8	10	5	5	8	6	7	5	4	3	250

TABLE XVIII

Relative position of lingual (condensed)

Proportionate number	37–39	40–42	43–45	46–48	49–51	52–54	55–57	58–60	61–63	64–66	S.
Number of cases	2	7	22	38	53	40	35	20	21	12	250

TABLE XIX

Relative position of lingual (per cent distribution)

	per cent
Median value (49–51)	21.2
Extended median value (46–54)	52.4
Lower distribution (37–45)	12.4
Higher distribution (55–66)	35.2

SUMMARY

1. The width of the ramus varies between such broad limits (20 to 44 mm.) that any method fixing the depth of penetration of the needle must lead to failure or partial failure in a considerable number of cases. If the ramus is too broad the needle may not reach the pterygomandibular space; if it is too narrow a great part of the solution is deposited into the parotid gland. As a consequence symptoms of facial paralysis will appear but anesthesia will be imperfect if obtained at all. The depth of penetration must be determined separately in each case on the basis of the width of the ramus. This can be found readily by placing the thumb on the anterior margin, intraorally, and the index finger upon the posterior margin, extraorally, and thus holding the ramus between the fingers.

2. The inclination angle of the ramus to the median plane varies between such broad limits (0 to 27 degrees) that those methods which prescribe an exact direction and aim to lead the needle to the lingula by bone conduct give poor results in a large number of cases. The point of the needle can reach the inner surface of the ramus at an acute

angle only when the needle is placed on the periosteum and in this case it cannot be carried to the lingula without danger of breaking. The direction of the needle in each case must be determined on the basis of the inclination angle of the ramus to the median plane. This may be determined approximately by inspection based on experience and anatomical studies considering that variations in the inclination angle cause visible and recognizable variations in the exterior configuration of the face.

3. The relative position of the lingula on the inner surface of the ramus varies, sometimes considerably, from the median value of 50. All procedures which specify the point of injection on the same level with the masicating surfaces of the mandibular teeth, or near to it, lead to failure in certain cases. When the lingula is above the average height (one third of the cases) the needle does not reach the pterygomandibular space but passes between the fibers of the internal pterygoid muscle. Methods designating a higher point of injection, at the bisecting point of the distance between the mandibular and maxillary teeth, are more practical.

These results were obtained by measuring 750 mandibles. The material is numerically insufficient for the formation of anthropological-anatomical rules of general validity concerning the whole mandible. It is believed, however, that the number of mandibles examined was sufficient to prove the great variability. This variability requires, in mandibular block anesthesia, more freedom of individual judgement based on corresponding anatomical studies and experience.